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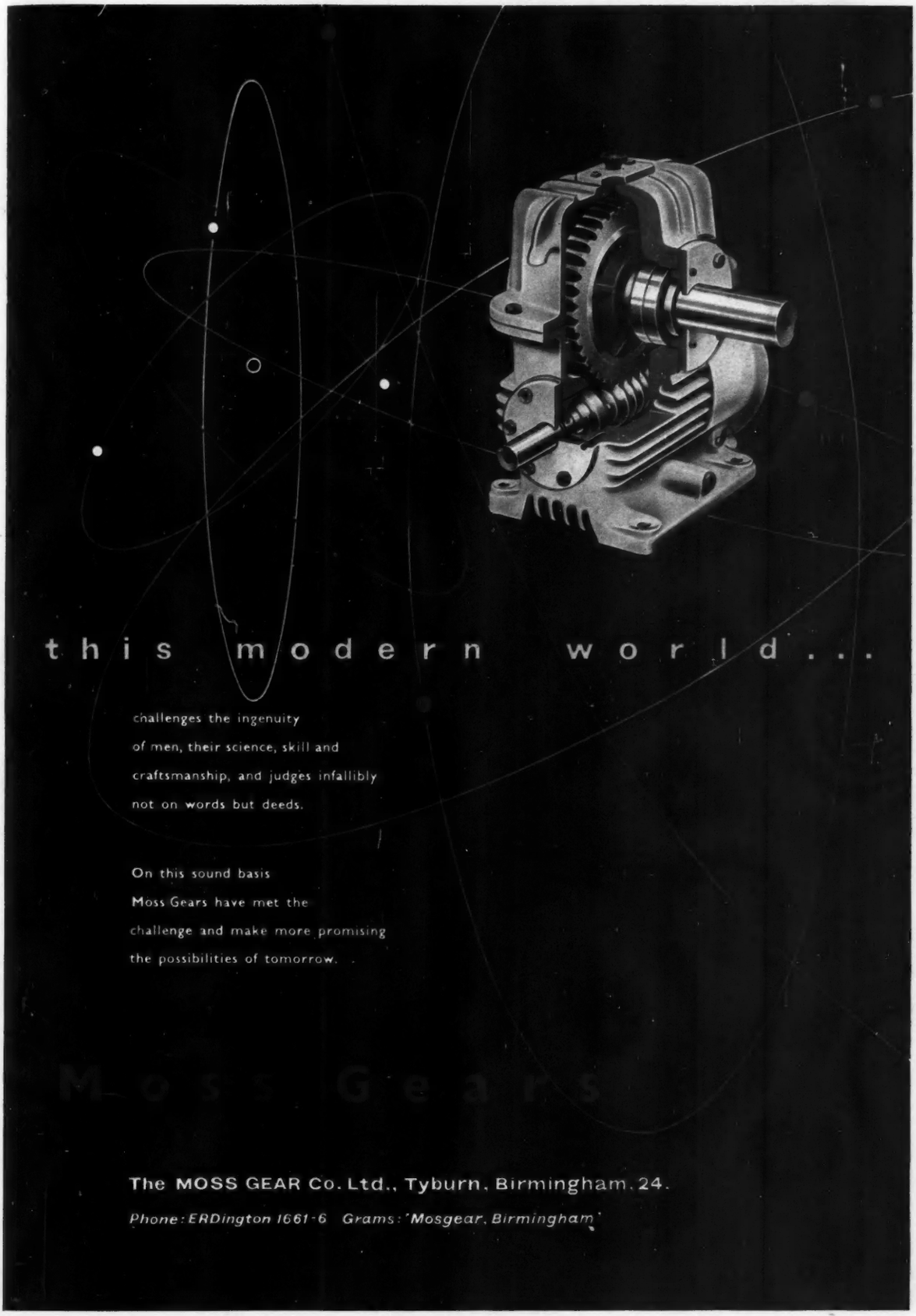
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THE ENGINEER

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THE BUDGET, MUCH AS EXPECTED

The socialists, it is certain, will not like the Budget. Indeed, considered in isolation from past Budgets and the kind of Budget which the conservatives, no doubt, hope to be able to present next year, and considered too exclusively in relation to the tax reliefs that it offers, the Budget is open to criticism. The main beneficiaries are people with incomes of over £2000 per year ; for though the easing of purchase tax on household goods, the removal of duty upon sport and the easing of duty on the cinema will benefit those with smaller incomes, that benefit will not be at all large. Furthermore, people within the range of £1000 to £2000 a year, a range which covers the majority of young and many middle-aged executives, benefit not at all if unmarried or only with young children and not very much if their children are older. But tempting though it is to look at the Chancellor's proposals in that way—for it is always tempting to grumble when others are seen to benefit—it should also be noticed that the Chancellor's reforms in the surtax range are, as he said himself, long overdue. The effect may be disinflationary, particularly if, by degrees in future Budgets the sharp increase in taxation, as incomes become higher, can be further eased. For, before this Budget—there is not even now much difference—firms wishing to hold higher executives of talent had to offer them relatively enormous increases in salaries merely to increase their standards of living by small amounts. Now that a correction has been made it can be hoped that in future Budgets benefits will be more equally shared.

In fact, of course, regarded as a whole, the Budget amounts to one of standstill. Within the very small range for manœuvre open to him the Chancellor has chosen only to correct certain more obvious ills. The unduly steep incidence of tax upon higher incomes has been eased. Partly, perhaps, out of fright that a substantial British tonnage of ships might be transferred to flags of convenience, investment allowances have been increased for shipping companies. The long-standing anomaly of unduly heavy taxation of companies trading abroad is to be removed. But there is no more encouragement in this Budget than in the last for industry to increase its rate of investment and there is to be no relaxation of the credit squeeze. There is little encouragement by relief of taxation to people to increase consumption expenditure ; and no doubt the Chancellor hopes that the reliefs granted to surtax payers will largely be balanced by increased savings. Broadly, in fact, the economy is to be left as it is. There is, however, one proposal of especial interest. It is that a committee should be set up " to enquire into the working of the monetary and credit system and to make recommendations." The socialist idea after the war and one that socialists still appear to favour, was that the Government should retain close control upon the activities of industry and, indeed, of almost of every facet of the economy. The conservatives, by contrast, expected to regulate the system by the pre-war method of managing the Bank Rate and by Exchequer financing and open market operations. Yet, when put to the test in post-war conditions, that system has not worked well. It has had to be supplemented by the work of the Capital Issues Committee and by direct appeals to the Banks ; and its effects have been too slowly felt in their reactions on the economy. Whether, in fact, any means of monetary control would be able to hold the value of the pound stable despite annual demands for higher wages remains doubtful. But it is certainly much to be desired that some means of regulating the economy, which would prevent the violent fluctuations experienced in this country since the war, should be found. Many signs, notably the rate at which orders are being received by industry, suggest that the coming financial year will show an up-turn in the country's fortunes. New productive capacity is available and there seems no reason why output and exports should not improve. What needs to be avoided is the over-development and over-stretching of the economy that has followed every such advance since the war. A means of regulation is wanted which can become effective immediately any signs of over-stretch appear and which will not unduly affect investment in new

productive capacity as the credit squeeze does. Perhaps the committee will find such a means.

THE DEFENCE WHITE PAPER, 1957

After the failure of the 1947 Moscow Conference, there was never any doubt about the tasks required of our Armed Forces. They have, with their Allies, to play their part in deterring and resisting aggression, and to undertake limited operations in defending our interests overseas. To-day, for the first time, the Government has reached a definite decision on the relative importance of these tasks and on the types of forces and weapons required to achieve them. The Defence White Paper—which shows a net estimated expenditure for the coming year of £1420 million—is, in fact, an outline of British defence policy over the next five years, and the Defence Minister rightly claims that it involves the biggest change in military policy ever made in normal times. Put briefly, the change lies in the admission that the people of this country cannot be given adequate protection from attack by nuclear weapons. This means that the prevention of war, rather than preparation for it, is now the overriding consideration. And as prevention largely depends on the deterrent fear of nuclear retaliation, the defence of our bomber bases is regarded as no less important than building up a bomber force. The defence of these bases is considered feasible with a manned fighter force, smaller than at present, but equipped with air-to-air guided missiles, which, in due course, will be replaced by a ground-to-air guided missile system.

The White Paper gives evidence of clear and logical thinking, but in some respects is far from convincing. As Mr. Sandys points out, the large reduction in manpower forecast by 1962 will not be accompanied by a comparable fall in the level of defence expenditure. Where, then, is the money to come from for the very expensive guided missiles and missile systems ? For some years we have spent as much as we could afford on guided missiles, with an annual budget of £1500 million. Yet we have produced only one air-to-air missile (already out of date) for R.A.F. operational training and one surface-to-air missile still under test for Fleet use. The Americans began developing guided missiles four years before us. It is not, however, their experience, or "know-how," but adequate finance that has enabled them to arm all three Services with various types of these missiles. Again, by 1962, it is hoped that the present figure of 690,000 men in the Armed Forces will be reduced to 375,000—all Regulars—and that the call-up will cease in 1960. This would mean an Army of 160,000—more than double the number of Regulars now serving. Judging by the number of additional recruits resulting from the recent substantial increases in pay and pensions, it is difficult to see how we shall acquire a Regular Army of this size. To compensate for the considerable reductions in our Continental Army and in our garrisons overseas, a Central Reserve is to be maintained in Britain, with the necessary transport aircraft for the dispatch of reinforcements at short notice.

There is need also for more information on the Government's proposals for delivering the deterrent. Further development of the supersonic manned bomber is to be abandoned and reliance is to be placed on the types of bombers we have, supplemented by ballistic rockets. The latter—of medium range—are to be received from the United States. From what bases are these rockets to be launched ? As already pointed out in these columns, ballistic rockets with a range exceeding 1500 miles are unlikely to be developed for some years. Indeed, it will be surprising if the American rockets—the "Jupiter" and its naval version "Polaris"—which will shortly be in production, have a range greater than 1000 miles. Launched from Britain, they might just reach Moscow, but certainly not the vital targets further east. To reach these important targets, medium-range rockets must be fired from ships as the Americans intend to do. This will also ensure that that part of our retaliatory power which is to be provided by rockets will not be eliminated by a sudden and surprise attack. For ships can be and will be at sea before the outbreak of hostilities. The Americans are now fitting out two large merchant vessels to test a prototype "Polaris." Is it too early for us to do likewise ? Or is it really intended—as implied in the White Paper—that the Royal Navy should henceforth be restricted to carrier groups "to bring power rapidly to bear in peacetime emergencies or limited hostilities" ? The Navy, in fact, is given no role to play in a global war apart from sharing in the defence of Atlantic communications if we manage to survive a nuclear attack. Not only is our active service cruiser force to be reduced, but the cruisers which are in due course to replace them are not to be the much-talked-of guided missile cruisers, but the three ships of the "Tiger" class. These vessels were designed during the war and are now completing after being laid up for nearly ten years.

TWO EVENTS OF YOUTHFUL IMPORTANCE

Within the last fortnight there have occurred two events of particular interest to youth in this country. The first in point of time was the delivery at the Institution of Mechanical Engineers of Leonardo da Vinci lecture for boys on March 28 ; the other the holding of the third reunion dinner for Federation of British Industries overseas scholars on April 2. Last year there were three Leonardo lectures delivered on successive days. Those lectures, the first boys' lectures to be presented by the Institution, were excellent of their kind. But they brought from us the criticism that they were not as well adapted to serve their purpose as they might have been. They laid emphasis on the things engineers make and how those things work ; whereas since the object of the lectures is to interest boys in mechanical engineering as a career, it would, we suggested, be sounder to put the emphasis on what engineers do and how they do it. This year the lectures were concerned with the "Design, Development and Performance of the Speedboat 'Bluebird,'" and they conformed much more closely to the desired end because the speakers, Donald Campbell, P. T. Fink, L. H. Norris, D. M. Smith and Leo Villa, represented the user and tester, aeronautical designer, consulting engineer, engine designer and mechanic. A truer picture was given of the work of mechanical engineers and the conditions under which their work is done. The fact that the boys listened to the successive speakers with undiminished interest for about 2½ hours, including a short break, indicated how successful the presentation was.

The other event, the F.B.I. Scholars' dinner, had, of course, no relation to the attraction of boys to an engineering career. The scholars are drawn from many parts of the world including, besides the Commonwealth, several Latin American and Middle Eastern nations. They have already graduated and had an engineering training abroad and are carefully selected as outstanding young men. Once selected for scholarships, the Federation places them with selected firms in this country which collaborate in carrying out the scheme, to give them the kind of experience which they wish to gather. The objects of the scheme are to give the scholars the opportunity to gain further experience so as to fit them to play a leading part in their own countries when they return to them ; to make them familiar with British engineering practice ; and to give them the opportunity "to observe the British way of life." Particular attention is paid to this last object and every effort is made to ensure that scholars will leave this country with happy memories of their stay. If we may judge by the three speeches made by scholars at the dinner, there can be no doubt at all that they do go back to their countries with a high respect for British engineering abilities and a not inconsiderable affection for the British people. It is pleasing therefore to note how rapidly the number of overseas graduates taking advantage of the scheme is increasing.

A Seven Day Journal

The Budget

THE Chancellor of the Exchequer, Mr. Peter Thorneycroft, presented his Budget to the House of Commons on Tuesday afternoon. In his speech he said that three main considerations had been kept in mind in framing the Budget, namely, greater industrial efficiency and competitiveness ; the provision of better incentives and opportunities for initiative and effort, and the easing of the pressure of the tax system where it bore most hardly on individuals and families. But the Chancellor stressed that the general pattern of the Budget was dictated by the need to place and keep our external position on a sound footing.

The estimated expenditure for the current fiscal year is £4827 million, and the estimated revenue is £5289 million, so that the estimated surplus is £462 million, compared with a realised surplus of £290 million in 1956–57. Overall taxation this year is to be reduced by £98,000,000. The tax reliefs include an extension of the earned income allowance of two-ninths from the present level of £2000 up to £4000, and then at the rate of one-ninth up to £10,000 ; increased allowance for children at the age of twelve, and concessions on income tax for people aged sixty-five and over. Various allowances which at present apply to income tax are to be extended to surtax, and for a married couple the surtax starting point is to be £2100. There are various concessions on entertainments tax, but combined television and sound radio licences are increased by £1. Purchase tax on kitchen equipment and furniture has been reduced from 30 to 15 per cent, and the additional shilling a gallon on petrol, imposed last November, has been removed.

The concessions applying most directly to industry concern shipping and overseas trading. Investment allowances for capital expenditure on the construction of new ships have been increased from 20 to 40 per cent. Overseas trading profits earned by British companies, managed in this country, but with all trading operations abroad, are to be exempted from income and profits tax. But this concession will not apply to dividends nor to shipping or finance activities.

British Electrical Exports

OVERSEAS trade takes a prominent place in the annual report for 1956–57 of the British Electrical and Allied Manufacturers Association (BEAMA). The report shows that in the year concerned, the electrical manufacturing industry became the largest exporting industry in the United Kingdom, with a total of £272·5 million, surpassing by 11 per cent its total for 1955. These exports represented about 23 per cent of the industry's total production. For comparison, electrical exports during the same period from the U.S.A. reached £347 million (6 per cent of the total production), and from Western Germany £212 million (20 per cent of the total production). Over the past five years Germany's share of the total world export trade has increased from 11·5 per cent to 19·3 per cent, while Great Britain's share has declined from 28·1 per cent in 1952 to 25 per cent in 1956.

Commenting on the emphasis which the Government appears to be placing on the encouragement of inter-European trade, the report raises the question of the development of trade ties with the Commonwealth which, in terms of sales of manufactured electrical goods and the purchase of essential raw materials such as copper, is of far greater importance to the electrical manufacturing industry. For, whilst the Messina countries took £26,200,000 of electrical machinery and goods from Great Britain in 1956, exports to the Commonwealth were valued at £142·1 million, or 52·3 per cent of Britain's electrical export. Nevertheless, because 9·7 per cent of the industry's exports were to the six Messina countries and 8·8 per cent to the other O.E.E.C. countries, the report acknowledges that the United Kingdom has virtually no alternative but to participate in a European trading arrangement of some kind. It is suggested that " there is much to be said for a trial period to see how things develop before committing the nation irrevocably on a long term basis."

The industry's participation in the 1958 Brussels World Exhibition is the subject of a long chapter in the report. There is to be a United Kingdom Government Pavilion and, in response to an appeal made to British industry by the Board of Trade, the BEAMA has accepted responsibility for the planning and administration of the collective exhibit. Other associations have been invited to participate and the BEAMA has been joined in this venture by the Water-Tube Boiler Makers Association, the Radio Communication and Electronic Engineering Association, the Telecommunication Engineering, and Manufacturing Association, the Cable Makers' Association, the British Radio Equipment Manufacturers' Association, and the Electric Light Fittings Association.

The Engineer
100 Years Ago
(APRIL 10, 1857)

" EXPERIMENTS AT WOOLWICH "

" Some experiments on an extensive scale were performed on Saturday at Woolwich Marsh. The Commander-in-Chief, before proceeding to the Marsh, conducted the Lords of the Admiralty to the royal carriage square, in order that they might examine the equipment prepared for the Chinese war. His Royal Highness, on a former occasion, had expressed his approbation of the 3-pounder batteries, in which their Lordships readily concurred, and, to verify the facility with which the ammunition wagons are convertible for the easy transport of the wounded, the Duke desired an attendant to enter one of the vehicles, when his Royal Highness having wheeled it forward some paces, again repeated to Colonel Tulloch his admiration of its compactness and efficiency.

" They thence proceeded to the marshes in Plumstead, where, notwithstanding the incessant fall of rain throughout the day, the proceedings commenced, as arranged, precisely at two o'clock. The first experiment was with several wrought and cast-iron shot from 68-pounder guns, fired at a wooden butt faced with sundry sample plates of sheet-iron three quarters of an inch in thickness. The first shots were over a flight of 1,200 yards, which was ultimately reduced in proportions of 200 yards, and they were finally fired at a proximity of 400 yards from the target. Attention was then directed to the scantling of a 36-gun frigate, erected for the purpose of testing Martin's shells (containing a charge of 28 lb of molten iron) in the destruction of ships of war. The point of attack showed a perfect broadside, resembling a ship at sea, into which a number of shells and redhot shot were alternately projected, over various ranges varying from 1,200 to 400 yards, giving ample time between each discharge to observe the effect. It was remarked that the ignition produced by the liquid iron was considerably more speedy and effectual than by the agency of redhot shot."

Ground Movements Due to Mining

THE first European Congress on Ground Movement has been in progress this week at the University of Leeds, and the final technical sessions are taking place to-day. The congress is concerned with ground movements due to mining, and about a score of papers on this complex subject have been prepared for the congress by authors from many of the principal European mining areas. A general review of the subject was given as an introduction to the congress by Professor Whetton, and we reproduce his remarks on page 562 of this issue. Succeeding contributions dealt in greater detail with specific aspects of the subject, including results of recent field measurements and researches, all grouped under the three general headings of " surface movement," " underground movement," and " laboratory tests and theory." The congress was of importance in stimulating discussion of problems which are as yet by no means completely solved. As one contributor remarked, the vital questions of strata control in the mine which directly affected surface movement might also directly affect safety and production, and the prizes to be gained from effective application of knowledge in this field were considerable.

Apprenticeship in the Plastics Industry

PARTICULARS of a pupil apprenticeship scheme for the plastics industry have been published by the Plastics Institute. Under this scheme the Institute undertakes registration of pupil-apprentices and will issue certificates to those who have completed apprenticeship and technical training in accordance with the details of the scheme. The scheme embraces existing pupil-apprenticeship schemes operated by individual firms and existing educational facilities. It takes in apprentices of chemical firms manufacturing raw materials, apprentices of machinery manufacturing firms, and firms making tools for the plastics industry. The main object of the scheme is to enable youths to undertake a systematic training in either the chemical or engineering side of the industry, which is integrated with appropriate technical education.

No prescribed course of practical training is laid down for the scheme, but it will be required of a firm to submit evidence that systematic and comprehensive training can be provided for an apprentice registered under the scheme. In addition to practical training, it will be required that the apprentice should make the normal one day a week attendance at technical classes, although provision is made for " sandwich " or other approved kinds of courses. The Institute will grant apprenticeship certificates automatically to those attaining at least the minimum examination standard, whose apprenticeship has been registered and whose indentures have been satisfactorily completed.

Hydraulic Lock at High Pressure

By K. J. WHITEMAN*

For low pressures existing theory indicates that the locking force in piston valves due to the presence of tapered clearance gaps varies linearly with pressure and is independent of the fluid viscosity. Experiment confirms this for pressures up to about 1000 lb per square inch. For higher pressures the theoretical approach suggests that distortion of the metal parts and the change of viscosity with pressure will modify the pressure forces on the piston. The experiments reported in this article show the divergence of the locking force from a simple linear law and confirm that for sufficiently high pressure the locking force can vanish. From the tests it was not possible to draw any definite conclusions regarding the viscosity/pressure effect : for pressures up to 10,000 lb per square inch and fluids having pressure/viscosity coefficients (ϕ) of the same magnitude as those used in the tests, the effects are probably of minor importance. This effect could be significantly larger in the unlikely event of piston valves being used at pressures much greater than 10,000 lb per square inch, or the more likely event of synthetic hydraulic fluids being used with ϕ values much larger than those at present encountered.

THE piston control valve is widely used in hydraulic systems to control the flow of oil under pressure and has many features to recommend its use. It is a relatively simple mechanism consisting essentially of a double-ended piston and a cylinder with ports. The clearance between piston and cylinder can be made extremely narrow so that the leakage past the piston lands is small even at high pressures. At first sight it also seems to have the advantage that the hydraulic forces are balanced and that negligible force should be required to move the piston in its cylinder. However, it is occasionally found that a valve which can be moved freely at first, jams when pressure is applied. Where the valve is hand-operated this may mean the operator exerting a greater force to move the valve or even using a hammer to free it. Where the valve is part of an automatic system and is actuated, for instance, by a solenoid able to exert only a limited force, this locking of the valve would prevent the system from working altogether. This phenomenon of valve jamming is known as hydraulic lock.

An explanation of it has been given by Sweeney[1] and Blackburn[2] who have shown that tapered clearances between the piston and cylinder can cause sideways forces pushing the piston against the cylinder wall. The locking force is the friction engendered by this lateral thrust. It has also been suggested that this phenomenon might be due to solid particles in the oil becoming wedged in the clearance gap and causing the piston to jam in the cylinder. Both types of lock occur in practice, but there is one major difference between the two. With the first type the lock occurs only while the pressure is applied, but with the lock caused by dirt the lock will persist to a certain extent even when the pressure is released. The latter has become known as " dirt " or " muck " lock to differentiate it from the former known as hydraulic lock.

The way in which tapered clearances produce hydraulic lock can be explained, simply, as follows. When pressure is applied to a piston control valve a difference in pressure is created between the piston lands and oil leaks along the fine clearance between the piston and cylinder. There is a gradual pressure drop along the clearance from the high-pressure to the low-pressure end and this pressure acts as a normal force on the piston. If the piston and cylinder are axially symmetric and concentric with respect to each other, the pressure forces and the flow are axi-symmetric and cause no resultant sideways force to act on the piston.

If, however, the piston is displaced a little from its central position in the bore, the pressure forces need no longer cancel. This is illustrated in Fig. 1. Fig. 1*a* shows

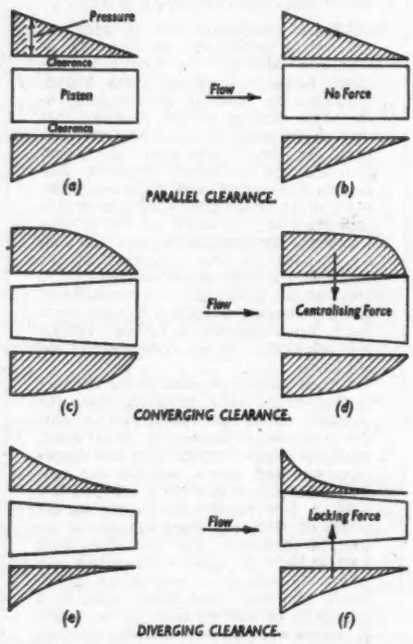

Fig. 1—Pressure drops in clearance gaps

the case of a parallel clearance. Since the flow is viscous (the small clearance gaps and high viscosity oils tend to make the Reynold's number in the clearance gap small) the pressure drop along the clearance is linear. If the piston is displaced slightly sideways (Fig. 1*b*) the clearance is still parallel all round the piston, the pressure drop is still linear and there is still no resultant side force. The piston, in fact, is in equilibrium irrespective of its position in the bore. It might be argued that the piston could tilt in the bore, but in this case, because the piston is double ended, the fluid forces would push it straight again.

For a converging clearance the pressure drop is as shown in Fig. 1*c*. Most of the pressure drop occurs at the end where there is most constriction. If such a piston is now displaced sideways the pressure drop is not the same all round the piston as shown in Fig. 1*d*. At the side nearest the cylinder wall the constrictive effect of the taper is greater, causing a greater average pressure on this side of the piston than along the opposite side. As a result, there is a sideways thrust on the piston tending to push it back into its central position ; that is, a piston with a converging clearance is in stable equilibrium when situated centrally in its bore. If for any reason it is displaced from this position the fluid forces tend to centralise it again. The case shown in Figs. 1*e* and 1*f* is when there is a diverging clearance gap. In this case, when the piston is displaced from its central position, the fluid forces tend to push it further sideways until it reaches the wall. The piston then exhibits hydraulic lock, the friction caused by the thrust of the piston on the cylinder wall having to be overcome before the piston will move.

The explanation given above is only an approximate one. A quantitative explanation can only be obtained by taking into account the fact that if the pressure is different at positions around the circumference of the piston there will be a flow of liquid around the piston as well as along it. To determine the flow pattern accurately it is necessary to solve the equation of flow in the clearance gap.

For viscous flow in a narrow clearance, width h, the rate of flow is given by Poiseuille's formula :

The rate of flow in the direction x per unit width of flow path

$$=\frac{-h^3}{12\mu}\frac{\partial p}{\partial x} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where

p = pressure,

μ = the absolute viscosity of the fluid.

The flow must also satisfy the equation of continuity, i.e. the rate at which liquid passes into an element of volume of the clearance space must equal the rate at which it leaves. If in the clearance gap between a piston and cylinder we measure x in the direction of the axis of the piston and y around the circumference from some fixed point, then the equation of continuity becomes

$$\frac{\partial}{\partial x}\left(\frac{h^3}{12\mu}\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{h^3}{12\mu}\frac{\partial p}{\partial y}\right)=0 \quad . \quad . \quad (2)$$

This is the equation which must be solved in order to find the pressure distribution around the cylinder. The side thrust on the piston is then found by integrating this pressure distribution over the piston surface.

The difficulty in solving the equation is that for relatively simple configurations of piston and cylinder, the expression for h, the clearance gap, becomes quite complicated. For the case of a tapered piston in a parallel bore with the piston touching the cylinder wall the expression for h is[3] :

$$h=\frac{xt}{L}+c\left(1-\cos\frac{2y}{D}\right) \quad . \quad . \quad . \quad (3)$$

where (see Fig. 2) t is the taper, c the clearance, L the piston length and D its diameter.

A general solution of this equation has not been obtained, but it can be shown that the side thrust on the piston F is of the form

$$F=PLDG \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where P = the pressure drop across the piston and G is a function only of L/D, the length/diameter ratio of the piston, and t/c, the taper/clearance ratio.

It is of interest to note that if the viscosity is assumed constant it cancels from equation (2). That is, the side thrust is independent of viscosity, the only property of the fluid that enters the equation.

Although a general solution of the flow equation for the case of a tapered clearance gap is not possible, some particular solutions have been obtained. Blackburn[2] has obtained

* British Hydromechanics Research Association.

the analytical expressions for G in the two limiting cases where L/D tends to zero and L/D tends to infinity. The first solution is shown in Fig. 2 and for the second $G=0$ for all values of t/c. Manhajm and Sweeney[3]

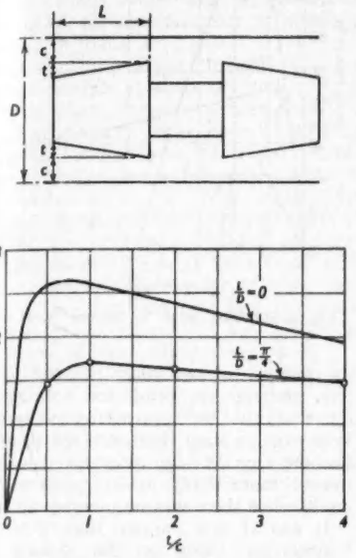

Fig. 2—Transverse force G, against taper clearance ratio t/c

have solved the equation numerically for the case $L/D=\pi/4$ and this, too, is shown in Fig. 2. Royle[4] has by a similar method obtained curves of G for several L/D values, but the calculations were not carried so far and the results are not so accurate.

The validity of this explanation of hydraulic lock has been amply confirmed by experiment and good agreement has been obtained between the theory and experiment for operating pressures up to about 1000 lb per square inch. For pressures substantially above this range, however, other factors can be expected to influence the flow in the clearance gap and, consequently, the locking force. The clearance gap has, for instance, been assumed to be of constant size at all pressures, but for pressures of several thousand pounds per square inch the distortion of the piston and cylinder can be of the same order of magnitude as the initial clearance. Again, the viscosity has been regarded as constant; but the coefficient of viscosity for an oil can have a value at 10,000 lb per square inch, four or five times its value at atmospheric pressure. As a result when the pressure drop along a piston is large, the viscosity at one end can be quite different from that at the other.

Allowance can be made in the flow equation for these high-pressure effects. For example, standard works on stress analysis (such as ref. [5]) give formulæ for the distortion of thick-walled cylinders under internal pressure. For a cylinder of internal radius b, external radius c, the increase in internal radius due to a pressure inside the cylinder is:

$$\Delta b=\frac{pb}{E}\left(\frac{c^2+b^2}{c^2-b^2}+\sigma\right),$$

where

E=the Young's modulus of the cylinder material

and

σ=Poisson's ratio for the material.

The decrease in radius of the piston due to compression is given by

$$\Delta b=\frac{pb}{E}(1-\sigma).$$

Giving a total distortion

$$\Delta b=\frac{pb}{E}\left(\frac{c^2+b^2}{c^2-b^2}+1\right)=Xp,$$

where X is a constant depending on the geometry and material of the piston and cylinder.

Where the pressure varies along the cylinder, as is the case in a piston valve, this simple formula for distortion will not be strictly true because of the neglect of the shear stress. However, it should be a reasonable approximation to the actual distortion.

We can therefore say that the magnitude of the clearance gap, which is h when no pressure is applied, is equal to $h+Xp$ at a point where the pressure is p. For example, with a 1in diameter piston in a 2·5in O.D. cylinder, both made of steel, the radial clearance gap increases linearly with pressure and is increased by 0·44 thousandth of an inch when the pressure is 10,000 lb per square inch. Since valves operating at pressures in the region of 10,000 lb per square inch have clearances of a few tenths of a thousandth of an inch, the distortion is appreciable compared with the initial clearance and the taper. For a piston having an initially diverging clearance (i.e. a locking piston) the distortion, which is greatest at the high-pressure end of the piston land, will tend to make the clearance less divergent. In fact, as the pressure is increased the distortion can change an initially divergent clearance first into a parallel clearance gap and, at even higher pressures, into a converging clearance. Under these latter conditions the piston should not lock. Another way of looking at this is to consider Fig. 2. This gives a graph of the function G for varying values of the taper/clearance ratio t/c. But due to distortion the taper/clearance ratio itself varies with pressure. As the pressure rises the taper/clearance ratio decreases to zero and finally becomes negative i.e. a converging clearance. As t/c tends to zero, the function G tends to zero also, which suggests that at sufficiently high pressure a piston which initially exhibits hydraulic lock should become free.

With regard to the variation in viscosity with pressure, experimental determinations of the viscosity of a great many oils show that the viscosity can be represented by an expression

$$\mu=\mu_0 e^{\phi p},$$

where

μ=coefficient of viscosity at pressure p above atmospheric pressure,

μ_0=coefficient of viscosity at atmospheric pressure,

and ϕ is a constant for a given fluid at a given temperature, the viscosity/pressure coefficient.

For example, Shell Tellus 27 having a ϕ value of 0·0018 at 50 deg. Cent. has a viscosity of 17·7 centipoises at atmospheric pressure and 64 centipoises at 10,000 lb per square inch. Typical values of ϕ when p is measured in atmospheres are given in Table I.

TABLE I

Fluid	ϕ (atmospheres^{-1})
Heavy fuel oil	Approx. 0·003
Kerosene	0·0010 at 30 deg. Cent.
Shell Tellus 27...	0·0018 at 50 deg. Cent.
Shell Tellus 15...	0·0013 at 50 deg. Cent.
Water	0·0000

The rate of flow equation (equation (1)) can be modified to allow for this: i.e. the rate of flow in the direction x, per unit width of flow path

$$=\frac{-h^3}{12\mu_0 e^{\phi p}}\frac{\partial p}{\partial x},$$

and allowing also for distortion (writing $h+Xp$ in place of h), the rate of flow

$$=\frac{-(h+Xp)^3}{12\mu_0 e^{\phi p}}\frac{\partial p}{\partial x} \quad . \quad . \quad . \quad (5)$$

The complete flow equation now becomes (in place of (2)),

$$\frac{\partial}{\partial x}\left(\frac{(h+Xp)^3}{\mu_0 e^{\phi p}}\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{(h+Xp)^3}{\mu_0 e^{\phi p}}\frac{\partial p}{\partial y}\right)=0 \quad . \quad (6)$$

μ_0 cancels from this equation but the term including ϕ, the viscosity/pressure coefficient, remains.

The task of obtaining numerical solutions of this equation would be far more arduous than solving equation (2), but some idea of the effect of pressure can be obtained quite simply. Equation (5) can be written as the rate of flow

$$=\frac{-H^3}{12\mu_0}\frac{\partial p}{\partial x} \text{ where } H=(h+Xp)e^{-\phi p/3}$$

This is similar to equation (1) with H replacing h. As an approximation, therefore, the solutions obtained for the simpler equation (2) can be used, but instead of t/c being regarded as constant it should be considered as dependent on pressure. Since the effective clearance H is given by

$$H=(h+Xp)e^{-\phi p/3}$$

we can define an effective taper clearance ratio U in terms of the effective clearance H at the two ends of the piston land.

Writing Hp=the effective clearance at the high-pressure end of the land.

Ho=the effective clearance at the low-pressure end, then

$$U=\frac{Ho-Hp}{H_p}$$

$$=\frac{(t+c)e^{\phi p/3}}{(c+Xp)}-1 \quad . \quad . \quad (7)$$

For $p=0$, U has the value t/c, the undistorted clearance value. The distortion effect is represented by the term containing X and the viscosity/pressure effect is included by the term in ϕ. It can be seen that the distortion effect decreases the effective taper clearance ratio U as the pressure increases, i.e. the distortion tends to make a diverging clearance into a parallel or converging one. The viscosity effect, however, increases U as the pressure increases; that is it tends to prevent the lock disappearing at high pressures.

Since previous experiments on hydraulic lock had not been continued to pressures above about 1000 lb per square inch, tests were carried out at B.H.R.A. both to extend the range of the experiments to 10,000 lb per square inch and to test the hypothesis that distortion and variable viscosity affect the locking force.

The hydraulic circuit used for the experiments consisted of a Towler axial plunger pump, which was supplied with oil from an enclosed tank with an air filter and which delivered oil at pressures up to 10,000 lb per square inch to the test cylinder. The leakage oil from the test cylinder and the pump by-pass flow drained into a second tank. A gear pump transferred this oil through a Micronic paper filter back to the main supply tank. The filtration arrangements were not designed to prevent dirt-lock of the piston, but merely to ensure that the pump was fed with reasonably clean oil.

The test piston and cylinder were arranged as shown in Fig. 3. The cylinder with connections to the high-pressure pump and a Bourdon pressure gauge rested on a hydraulic jack. When pressure was applied

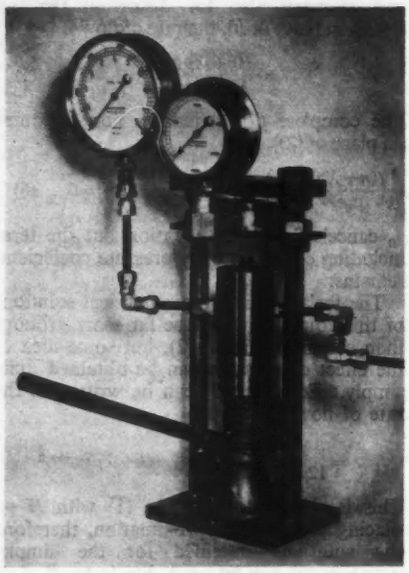

Fig. 3—Test rig

and the piston locked the locking force was measured by raising the jack, which pushed the top of the piston against a pressure capsule and gave a direct reading of the load applied to the piston.

The geometry of the test specimens is shown in Fig. 4. The pistons were made from SPM oil-hardening tool steel. After rough turning and hardening the pistons were ground to produce the small tapers required. Cylinder 1 (used with piston *A*) was made of

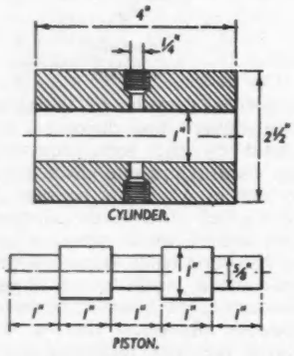

Fig. 4—Dimensions of test specimens

mild steel and cylinder 2 (used with pistons *B*, *C* and *D*) of case-hardened mild steel. The bores were lapped until a close fit was obtained with the test pistons. The clearance and taper dimensions of the test specimens are shown in Table II. The piston diameters

TABLE II

	t (inches)	*C* (inches)
Piston *A*	0·0001	0·0002
Piston *B*	0·0002	0·0002
Piston *C*	0·0003	0·0002
Piston *D* (converging clearance)	−0·0002	0·0004

were measured with a comparator and the cylinder bore dimensions with a micrometer plug gauge. The instruments could be read to the nearest 0·0001in and the probable error is therefore of the same order.

The test procedure was to position the piston in its cylinder, switch on the pump and with the pump by-pass valve adjust the pressure to that at which the test was to be made. After waiting for a predetermined time the locking force was measured by raising the jack and pushing the piston against the load measuring pressure capsule. In low-pressure tests it is often found that, once the locking force has been overcome and the piston has moved slightly, the locking force disappears for a time. For the high-pressure tests, however, this did not happen. As the jack was raised the dial of the pressure capsule would show an increasing load until the locking force was overcome and the piston moved. As the jack was further raised and the piston continued moving in the cylinder, the load measurement would remain constant, indicating a steady force opposing the piston motion.

Preliminary tests were made on all specimens to see for what time it was necessary to apply the pressure before the locking force attained a constant maximum value. After raising the pressure from zero to the working pressure, it was necessary to wait for periods of up to thirty seconds before the locking force built up to its maximum value, and so in subsequent tests of this sort the pressure was applied for one minute before locking force measurements were made.

Tests were also carried out to determine the repeatability of locking force readings for the same relative positions of piston and cylinder. It was found that the values of locking force were generally within 5 per cent of the mean value for a given pressure.

The position of the piston in the cylinder had an appreciable effect on the value of the locking force. Fig. 5 shows the locking

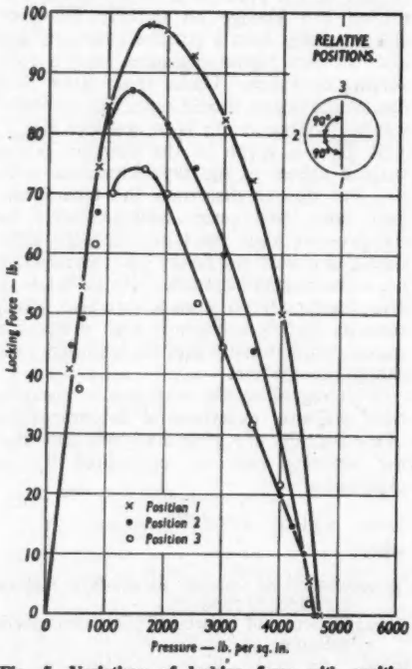

Fig. 5—Variations of locking force with position

force against pressure curve for piston *B* for various relative angular positions of piston and cylinder. Similar tests were made for the same piston reversed in the cylinder.

There was substantial variation in the value of the locking force shown in these tests, but for ease of comparison of results between different specimens a mean curve was drawn for each specimen. This was constructed from all tests on that piston and cylinder irrespective of relative position. This should not be too misleading, as the characteristics of different specimens were more diverse than the variations with position for a single specimen.

Fig. 6 shows these mean locking force curves for the three pistons and cylinders having diverging clearances. The single specimen having a converging clearance remained free within the pressure range of

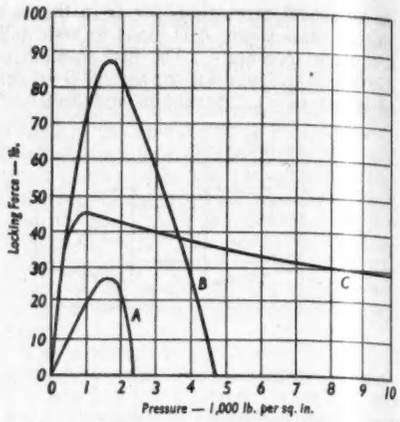

Fig. 6—Locking force for pistons *A*, *B* and *C*

the pump. In two cases the pistons came free and in the third the locking force decreased as the pressure was increased. It is worth noting that once the piston had become free at high pressure it could be moved more easily in its cylinder than it could when there was no pressure applied.

It was at first thought that there was a "hysteresis" loop on the locking force/pressure graph as, once a piston was freed at high pressure and the pressure was reduced to a value at which it had previously locked, the piston could still be moved quite easily. It was found, however, that under these conditions the locking force built up to its normal value if given time.

In all the tests carried out no serious locking force that could be attributed to dirt was experienced. In the initial tests on the build up of locking force the pressure was applied for up to twenty minutes at a time at pressures up to 10,000 lb per square inch, and the locking force remained sensibly constant after the first build up of the force. Sometimes, when the pressure on a locked piston was reduced to zero, the piston did not fall under its own weight, showing that a locking force remained, but this force was comparatively small and could be overcome by slight finger pressure.

It can be seen from Fig. 6 that at the low pressures (up to 1000 lb per square inch) the locking force does vary linearly with the pressure drop across the piston. But the most striking feature of the experimental results is that the rate of increase of locking force with pressure decreases and finally becomes negative with the result that for pistons *A* and *B* the locking force ultimately vanishes. The theory suggests that when the effective taper clearance ratio (equation (7)) becomes zero the locking force should disappear. Using equation (7) and the measured dimensions of pistons *A*, *B* and *C*, one can obtain the theoretical pressures at which the locking force should vanish. For piston *A* this pressure is 2300 lb per square inch, for piston *B* is 4600 lb per square inch, and for piston *C* is about 7000 lb per square inch. Another check between theory and experiment can be obtained by calculating the initial slope of the locking force curves with that calculated from Fig. 2. Using the curve of *G* for $L/D=\pi/4$ (as this should give values only a little larger than the true values for $L/D=1$), we find that $G=0{\cdot}14$ for piston *A* and 0·17 for pistons *B* and *C*. Taking the coefficient of friction between piston and cylinder to be 0·25 the locking force for pistons *B* and *C* at 1000 lb per square inch pressure should be about 85 lb and for piston *A* about 70 lb. The initial slope of the experimental curve for *B* and *C*

is about 80 lb locking force/1000 lb per square inch pressure, which is close to the theoretical value, but for piston *A* is only 20 lb/1000 lb per square inch. This suggests that *t*/*c* is smaller for piston *A* than the nominal value, and this is quite likely allowing for the possible error in measuring the taper of piston *A*.

Because of this it was probably fortuitous that the pressure at which the pistons *A* and *B* became free, agreed so closely with the calculated figures. For piston *C*, although the mean locking force curve did decrease with pressure, it did not become zero at the calculated value of 7000 lb per square inch. For one angular position of the piston in the cylinder it became free at 10,000 lb per square inch, but the mean locking force value for all measurements at this pressure was about 30 lb. This fact suggests that the piston was axi-symmetric and this may account for the shape of the locking force curve.

Further tests were carried out using different liquids to test the viscosity/pressure effect. Oils used were Shell Tellus 15 and 27 and a few tests were carried out using water as the fluid. The results, however, were inconclusive. For pistons *A* and *B* which became free at relatively low pressures, the change of viscosity with pressure would not be expected to have much influence in the locking force. For piston *C* no appreciable change was observed even at 10,000 lb per square inch. The theory suggests that the pressure/viscosity effect should stretch the locking force curve sideways at high pressures. Since for piston *C* the locking force value is almost constant between 5000 lb and 10,000 lb per square inch this effect if present would not be noticed.

ACKNOWLEDGMENTS

The author wishes to thank Towler Brothers (Patents), Ltd., for the loan of the high-pressure pump ; Mr. R. G. Goodwin, who carried out the experiments; and the Council of the British Hydromechanics Research Association for permission to publish the material contained in the article.

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Institution of Naval Architects

ANNUAL SPRING MEETING

No. II—(*Continued from page 525, April 5*)

THE meeting was continued on the morning of Wednesday, March 27, with Sir Stanley Goodall in the chair, and the reading of Paper No. 2, which was :

NATIONAL PHYSICAL LABORATORY NEW SHIP HYDRODYNAMICS LABORATORY

By J. F. ALLAN, D.Sc.

SYNOPSIS

The paper begins with a brief outline of the development of experimental tank work, with particular reference to the development of the Ship Division in the National Physical Laboratory. It then traces the development of the new Ship Hydrodynamics Laboratory, which is under construction at Feltham, and includes a table giving the main particulars of ship model tanks throughout the world. The history of the project is outlined and the various considerations leading to the final determination of size of tank, speed of carriage, &c., are recorded. Design and general details of the construction of various laboratory items are noted and include data relating to the main waterway, rails, carriage wavemakers, beaches, manœuvring and storage tanks, and the buildings themselves. A section of the paper deals with the water tunnel and resorber, which is also under construction on the same site, and there is a note on the progress of the work.

DISCUSSION

Mr. R. N. Newton : I would like to draw attention to a statement towards the end of Section II, from which one can assume the final cost to be of the order of £2,000,000. This sounds a lot, but I submit it is by no means generous considering the enormous dividends it will bring to this country. Also without such facilities we cannot expect to maintain our position as the leading shipbuilding nation. The cost of this first major addition to the nation's research facilities in this field in nineteen years (excluding the war years) represents about one-third of 1 per cent of the cost of the commercial ships built in this country in 1956.

A twin-screw motor ship of 19,000 tons gross requires about 19,000 b.h.p. for 22 knots and uses 19,000 tons of diesel fuel each year, assuming she operates for two-thirds of the year. At £20 per ton her total fuel bill in a life of thirty years is £11,400,000. Resistance and propulsion experiments often reduce the horsepower required by at least 5 per cent, which reduces this total fuel bill, for one ship only, by at least £600,000. The cost of the experiments represents no more than one-half of 1 per cent of this saving of cost. This example of the dividends which the new facilities will bring illustrates the value of research into ship hydrodynamics to the shipbuilding industry and how necessary it is for adequate experimental facilities to be provided.

The development work for the manœuvring tank being installed at the Admiralty Experiment Works, carried out with the assistance of Cambridge University, covered experiments on no less than twenty-eight different cross-sections for plunger wavemakers. Experiments were also conducted on the paddle and pneumatic types, but the final design chosen is the plunger with a cross-section which is basically a 15 deg. wedge with the angle for the upper portion increased to 25 deg. The paddle type was rejected because of the parasitic waves produced at the face of the paddle and which took some considerable distance to die out. The pneumatic wavemaker was rejected on the grounds of the higher power required and consequently higher cost. Although theoretically sound, a curved front plunger was found to be not so suitable for producing good waves over the complete range required, viz. from 40ft long by 2ft high to 5ft by 6in.

Dr. Allan mentions the phenomenon of cross waves. This was also a problem at A.E.W. and was one of the principal factors which governed the final choice of plunger design. Tests carried out at Cambridge University indicated that the formation of these cross waves is a fundamental feature of the plunger itself rather than the tank configuration.

The design of beaches is attended by similar difficulties. At A.E.W. twenty-three kinds of beach for the new manœuvring tank were tried and the final design comprises two tiers of wooden slats sloping back from just below the water surface to just above it. The beach is recessed into the wall of the tank and includes a trap between the wall and the inner edges of the beach. A half-scale version of the design has been tried and is being incorporated at the dock end of the extended Froude ship tank. Its efficiency is 99 per cent in terms of wave energy absorbed, i.e. the height of the reflected wave is between 5 and 10 per cent of the incident wave, and the " settling down " period of the tank is reduced from about twenty minutes to one and a half minutes.

Dr. Allan has remarked on the smallness of the manœuvring tank, 100ft square, compared with the new tank at A.E.W., which will be 400ft by 200ft, one-half of this 200ft by 200ft being the counterpart of the N.P.L. facility. What a pity the money could not be found for a larger tank for, as Dr. Allan points out, the problem of accommodating the recording equipment, even in large 20ft models, is difficult enough and there is much to be said for using the same size model in the manœuvring tank as in the ship tank.

Mr. C. L. Champion : The wavemaker follows closely a design worked out for another establishment and its servo-mechanism will probably be unique in its combination of power, amplitude and frequency. Experiments with a purely hydraulic servo led us to the conclusion that an electro-hydraulic link was required to obtain the desired accuracy. In addition to the in-phase component corresponding to the energy put into the wave train there is a large out-of-phase component which must be overcome, additional to the inertia of the wavemaker. Thus, even a pneumatic wavemaker behaves as if it had considerable inertia. The actual wavemaking process is fairly efficient, but if the drive is not reversible this out-of-phase component can lead to a wastage of power much greater than that theoretically needed for the waves.

We carried out some studies for an adjustable hydraulic-pneumatic spring which would form a tuned system with the virtual mass of the wavemaker so that the driving ram need only supply the in-phase force. However, as we have been able to obtain a hydraulic pump with regenerative characteristics, this will provide a simpler solution.

In the early work of the Ship Hydraulics Laboratory in 1949 we completed a preliminary design of a resorber very similar to that in California. When financial considerations stopped work we were requested to build a resorber for the Admiralty, and it became apparent that when the dimensions of a resorber were such to prevent it being built in one piece it was more economical to construct a circuit with sections not greatly exceeding 10ft in diameter, folded on itself several times. Experience gained in the construction of this project convinced us that the circuit of Fig. 5 extending to a much greater depth would be an economical proposition. This tunnel will be unique in having its working section rigidly anchored at ground level and this should be most advantageous. It may be asked why the lower limb is of somewhat reduced diameter. It is true that since this section is the region of highest pressure it would be better to have a low velocity. However, the reduction in diameter facilitated construction and will make it possible to fabricate the inner tube without *in-situ* longitudinal welds.

Mr. W. A. Crago : Table I presents certain

data which purport to give some idea of the various model test facilities now available in the world. One of the main characteristics specified is the length, but, as Dr. Allan points out in the text under Fig. 1, the effective length at any given speed will depend on the maximum available carriage acceleration, the deceleration, the emergency stop, length and so on. To illustrate this, it is worth noting that a tank of only 1000ft in length would be equivalent to the Feltham tank for the 50ft per second case if the acceleration could be increased from 0·1*g* to 0·2*g*. That is a saving of 300ft. Thus, a more significant characteristic to convey a tank's capabilities would be a curve showing test speed plotted against time or distance available at that speed. Such curves would show the tremendous advantage enjoyed by carriage systems where the towing motors are not carried on the carriage but at the end of the tank—an endless cable being used to transmit the drive. In this way not only is the carriage mass reduced but wheel slip is eliminated as a limitation on acceleration and the effects of cable stretch can be reduced to negligible proportions by careful design. Furthermore, the increased acceleration may well be obtained without increase of motor power because of the reduced carriage mass. At Saunders-Roe an acceleration of 0·2*g* is regularly used in the 600ft tank to accelerate the carriage, dynamometers and personnel to top speed, which is 50ft per second. In the No. 2 tank, where the carriage is remotely operated, the acceleration can be taken up to 0·4*g*. No doubt such a system was considered for the Feltham tank and perhaps the carriage size affected the issue.

I would like to emphasise the problems of condensation in the tank building. This can be troublesome, causing dynamometer errors, rapid deterioration of electronic gear, and a rough ride in the carriage. May one ask if the present N.P.L. tanks are satisfactory in this respect ? And it would be of interest to know how the rails at Feltham were aligned both in height and direction.

Is it proposed to install some device in the wavemaker controls to produce an irregular sea having any required components ? Does not Dr. Allan feel that irregular sea tests, together with appropriate statistical analysis techniques, will soon replace regular sea tests ?

With regard to the water tunnel, is such a depth absolutely necessary and would not a longer time at a lesser depth do just as well and be more cheaply produced ? Water tunnels have sometimes been compared on a power factor basis and, as defined by a formula, the new N.P.L. tunnel has a factor of about 2·7. However, the Pennsylvania State College 48in tunnel has been quoted as giving a value of 6·5 and this implies that much less energy is being turned into heat through losses. Since the refrigeration plant constitutes a fairly large proportion of the total costs of such a facility a high power factor is desirable.

Mr. John West : With these new facilities much more research work done will be precisely what the shipowner requires. On the shipowning side there is a great deal of work to be done on propellers, and we often wonder whether, with the higher speed ships, we may leave the screw propeller altogether and go to something quite new. Then there are the problems of stern design and of stern vibration, and also those associated with seakindliness and pitch and roll.

We also welcome this project, in that as shipowners we are interested in ship model research. We are building a 45,000-ton passenger liner, and by improving overall performance by a few per cent up to £7,000,000 can be saved on the fuel bill during its life. This is rather a staggering figure, but it is a real one.

Mr. P. R. Crewe : I am associated with the new Saunders-Roe tank and Table I, listing tanks over 200ft long, in active use, shows the contrast between our tank and that at Feltham ; one is the biggest and the other (ours) is the smallest in Britain. The maximum speed for our tank is misprinted in that table ; the greatest speed value is 50ft per second, and both these tanks can claim the same value.

It may be said that, in the tank world, the bigger the better, and therefore what is the point of having a small tank at all ? We agree that large tanks are excellent for making routine approval tests on expensive shipping projects, but they can prove quite costly and time-consuming for research and development work. It is the latter that we have particularly in mind at Saunders-Roe, and it is interesting to notice that our ordinary ship model size, about 10ft long, is the same as that proposed for the free-running models in the new manœuvring tank at Feltham. With regard to the manœuvring tank, the employment of a continuous wavemaker in one wall and an articulated wavemaker in the other may seem strange, but it seems to me that a completely flexible system of wave production so far as direction is concerned is given, provided the model is making a complete turn.

May I make a criticism about the limitation of speed in the return run ? Does not this prevent systematic investigation of high-speed behaviour in following seas ? We undertake a considerable amount of work of this kind, and find it necessary to operate up to full forward speed in what is nominally the return direction.

Mr. H. Lackenby : In 1909 Sir Richard Glazebrook read a paper to our Institution describing the tank facilities shortly to become available on a site prepared in Bushey Park. It is gratifying, forty-eight years later, to have a similar paper explaining the improved facilities at Feltham. The dimensions of the tank referred to by Sir Richard Glazebrook were 30ft by 12ft by 500ft ; the new tank is roughly twice as big in all directions. In that early paper Sir Richard went carefully into the problem of the maximum size of model that could be tested in the tank and it was concluded that the biggest model was 16ft long, which was roughly half the 30ft width of the tank. I am very interested to see from the paper that practically the same conclusion was reached in the case of the Feltham tank, that the biggest model they could test without side wall effect was 24ft long (half the 48ft width of the tank).

We have heard a lot about tank boundary interference on models, and more recently about interference in connection with ships. I am thinking of the monster tankers which will come along very shortly—some are out already—and before long the shallow water effects and the restrictive effect on these ships going through narrow channels may be a problem. One object of the tank at Feltham is to enable us to get away from boundary effects, and I ask whether the committee in charge of the project have considered the provision of special facilities for investigating these shallow water effects and the effects of restrictive boundaries generally.

This question of tank boundary interference takes me back to the discussion of the " Lucy Ashton " models in 1953. The value of the work on that set of geosims was greatly impaired by the fact that the larger models suffered rather badly from wall effect and impaired the light thrown on the extrapolation of those models ; I would be interested to see the " Lucy Ashton " models in this bigger tank, because there is not the slightest doubt that the 30ft model would be just clear of wall effect, and I think those geosims would be not only interesting, but would throw considerable light on the ship model extrapolation.

Professor E. V. Telfer : Some twelve years ago I was a member of the Froude Committee when the project of the Feltham tank first came out. At that time we had to decide whether we should have a new tank, rather than that we must have a new tank, and to clarify ideas on that problem Dr. Todd was given the task of visiting all the tanks of the maritime world and reporting back to the committee in order that we might make up our minds. I think it should go on record that Dr. Todd did prepare a very excellent report on the state of the art at the time, and very largely as the result of our reading that report we realised that, if for no other reason than keeping up British prestige in this matter, the problem was not whether we should have a new tank, but that we must.

It is gratifying that, even though it has taken twelve years to bring this matter to near completion, the early discussions of 1945 are bearing very real fruit.

As to Mr. West's remark on the commercial value of the tank work, I would stress what that means. It can mean that even a few per cent saving can amount to £7,000,000 in the course of a ship's life. But once you start assessing the commercial value of your scientific work you place yourselves in a position of contractual responsibility ; and it is just as easy to lose £7,000,000 as it is is to gain it ! I know Dr. Allan appreciates the seriousness of this, and the whole future of tank work depends on complete accuracy and being sure that whatever you are persuading your clients to adopt can stand the examination of a court of law. You have to establish that, beyond any possible doubt, the results obtained in the tank will be realised in practice. It is a problem which the tank experimenter has always avoided in public ; but you cannot keep up the avoidance for too long, and I am quite sure that ship correlation will be much more deeply and seriously considered as the result of this new tank, and that when he says there will be a saving of £7,000,000 he can actually guarantee that the saving will be £10,000,000.

The next paper presented on Wednesday was :

EFFECT OF CAVITATION IN THE PERFORMANCE OF A SERIES OF 16IN MODEL PROPELLERS

By R. W. L. Gawn, D.Sc., and Professor L. C. Burrill, M.Sc., Ph.D.

SYNOPSIS

Thirty propellers made to the same design, but having blade area ratios from 0·5 to 1·1 and face pitch ratios from 0·6 to 2·0, have each been tested at six cavitation numbers over a wide range of slip. The basic propeller of the series is of three-bladed design, having elliptical blades. The results are presented as thrust coefficients, torque coefficients and efficiencies to a base of advance coefficient and representative photographs illustrate the growth of cavitation with increasing slip and with decreasing pressure. The illustrations are generalised by a plotting of the extent of cavitation applicable to the whole series, indicating the growth of cavitation. The results show that for wide, thin blades the torque falls off before the thrust. Appendices record the model propeller measurements and discuss the use of the diagrams included in the paper.

DISCUSSION

Mr. A. F. Honnor : The authors have presented the data in the very minimum

number of diagrams and although this is convenient in certain respects, nevertheless, the relative influence of the prime variables on thrust and efficiency under severe cavitating conditions is not readily ascertainable.

In order to elucidate this point, I have replotted some of the curves in a slightly different form. From this incomplete analysis it can be shown that the loss of thrust due to the development of back cavitation occurs at lower values of thrust parameter as the blade area is reduced and is not significantly altered by pitch ratio. Face cavitation is shown to be equally damaging at the lower pitch ratios and lower blade areas

Whilst it is true that both back and face cavitation can be reduced to some extent by suitable designs of the blade section, nevertheless, the trends derived from this data may be taken as generally applicable to propellers with a wide variety of section shapes and, in view of the evident significance of blade area and pitch ratio with regard to face and back cavitation, I suggest to Professor Burrill that this aspect should be more exhaustively treated in the report which is being prepared.

Mr. R. N. Newton : The propeller designer is beset with the problem of choosing the best values of the most influential characteristics affecting efficiency, the problem being aggravated by the paucity of available information concerning many of them. Blade section shape, radial distribution of pitch and camber, are frequently fields in which designers exercise the latest theories, so that the series reported in this paper might appear to be pedestrian. The Admiralty decided, however, that the propellers should be generally similar in blade section to those which formed the comprehensive open water series reported by Dr. Gawn to the Institution in 1953. The object of this was to obtain an extension of this earlier series which would enable designers to take more accurate account of the effects of cavitation when analysing the trials of fast ships and applying the results to new vessels.

The additional information now presented will achieve this object so far as constant pitch, segmental section propellers designed for normal ship forms are concerned. The application of the data to propellers with other section shapes must be made with some circumspection.

It would be as well to warn the student that the problem of designing propellers to work under cavitating conditions does not end there and this latest data should not be applied directly without application of factors derived from experience. This is because the flow conditions pertaining to the full scale are very different from those in the cavitation tunnel and there is still a wide gap in correlation of model results and those obtained at sea.

I trust the authors will excuse one point of criticism which I feel to be important. This concerns the correction of the thrust and efficiency curves for tunnel wall effect. I feel that the validity of the corrections is questionable and still a matter for detailed investigation.

As the Committee dealing with Comparative Propeller Tests at the Seventh International Conference on Ship Hydrodynamics pointed out in 1954, there is scope for determining the influence of tunnel walls more definitely, both by theory and experiment. Attention was drawn to such factors as turbulence in tunnel water ahead of the propeller, effective area of the tunnel as determined by its sectional shape, non-uniformity of flow through the propeller disc, non-homogeneity of the fluid under heavily cavitating conditions, and Reynolds number effect.

One may ask what contribution the Admiralty Experiment Works have to offer in this connection. There is a possibility that experiments in the new and very large section cavitation tunnel may at least help in enabling a conclusion to be reached as to the size of propeller in relation to the area of a tunnel that can be used to avoid appreciable wall effect and at the same time avoid scale effect.

Mr. A. Silverleaf : Because this is the first publication of such experimental results it is important that we should discuss and, if possible, agree upon and establish a system of analysis of the results and the form of presentation, since more series of experiments will be run in the next few years.

On analysis, I mention the method of correction, the use of the Wood and Harris channel momentum correction factors. I hesitate to endorse Professor Burrill's statement that the aeronautical people accept them ; they prefer something better, and I think we agree that mathematically they do not apply under fully cavitating conditions.

Coming to the presentation of results, I want to emphasise that alternative methods are clearly available. It is possible that the full report will give some of these different methods. I suggest that, whilst the form of presentation in the paper is clearly a reasonable one, it has some obvious disadvantages. Professor Burrill has said that the corrected atmospheric curves agree very well with the equivalent open water results. Can he give a few details of comparisons of this nature ? The comparison of the thrust breakdown factors for different blade area and pitch ratios will be exceptionally useful and I suggest that you may get a more useful comparison by taking, not all the screws at a fixed σ and fixed blade area ratio, but by taking all the screws at varying blade area ratio or alternatively a group of varying σ and fixed blade area ratio.

Professor G. Aertssen : Even at this stage of the research the results will be a valuable tool in the hands of all those who have to design propellers. They will know where torque and thrust break down, and cavitation is taking place before that breakdown ; they will know, with the aid of diagram [Fig. 23] how to arrange their working conditions in order to avoid damage to the propeller.

I ask the authors if, in the same way as is done with ship model results and the results of ship trials at sea, it would not be useful to correlate as often as is possible the results obtained in the cavitation tunnel with the propulsion results at sea. That is possible when thrustmeters and torsionmeters are installed on a ship and careful readings are taken. A cross-channel ship, for instance, which in service has a speed of 20 knots, but which with her full power of 12,000 s.h.p., is capable of a speed of more than 24 knots, does not want to have propellers which do not cavitate in the exceptional high-speed conditions. Being designed, for instance, with a pitch ratio and a blade area ratio to give a good efficiency at 20 knots, they might cavitate, and probably do, at full power, with a speed of more than 24 knots. Carefully conducted measured mile trials, with measurement of power by torsionmeter and thrust by thrustmeter, will give in these conditions information which can usefully complete the work presented in this paper.

Mr. H. P. Rader : The variables not covered in this series are mean line and basic thickness form of the blade sections. May I show the effect of face camber which is the more important of the two variables for propellers working in cavitating conditions than for those free from cavitation effects. We have recently tested three propellers with a blade area ratio of approximately 0·73 having different face camber ratios, but practically identical analysis pitch ratios (i.e. identical values of J for $K_T=0$) and performance characteristics under non-cavitating conditions. These tests were carried out in the recently installed cavitation tunnel of Vosper, Ltd., in Portsmouth. It appears that for each rate of advance or slip there exists an optimum combination of pitch and camber which will depend on the type of mean line and basic thickness form used and also on the blade area ratio. The superiority of the cambered sections is due to their higher lift coefficients, produced mainly by the pressure on the blade face. Higher lift coefficients mean in turn lower drag lift ratio and higher blade element efficiencies.

Professor E. V. Telfer : I do not apologise for coming to the aid of Mr. Honnor and Mr. Newton in regard to the method of presenting the data which the authors have adopted. In the paper I presented at the recent symposium on education I said that one of our greatest troubles was to know how to improve the "putting-over" efficiency. Every paper presented to an institution such as ours, the contents of which have to be absorbed and then more or less analysed and eventually given to students, should be in a form which allows the man who does the analysing to absorb it quickly. It is quite impossible to do that with this paper. Moreover, most of the diagrams suffer from this particular defect and spoil the ability of the eye to take in what the authors have found in their researches generally.

I recommend that Fig. 20 should be devoted to one propeller, giving the whole story of the researches ; that is the best way to get an appreciation of the excellent work the authors have accomplished. The other diagrams are subsidiary and should be presented at a different stage in the contemplation of this work.

Evidently we are to have a lot of information, and I do feel that various points of view have to be considered in deciding which is the best presentation to adopt. Particularly the numerical system adopted by Professor Burrill is quite unfortunate, because he himself is in a difficulty in not having a continuous system of digits to define a continuous system of blade area ratios.

Mr. W. A. Crago : If one uses the data in the paper to design a propeller for a high-speed craft, I ask the authors whether or not one can take it that what has been called the quasi propulsive coefficient factor, which I think is a factor particularly favoured by the Admiralty, becomes unity. The data in the paper does take cavitation into account, and I understand that the factor it is supposed to allow for cavitation reaches a value of 0·7 with M.T.B.s ; in other words, there is a 30 per cent discrepancy somewhere between what should be obtained from the propeller and what actually occurs during trials.

Can the authors enlighten us on that point ?

(To be continued)

RAILWAY APPRENTICE TRAINING SCHOOL.—A new training school for apprentices has been opened at the Derby carriage and wagon works of the London Midland Region of British Railways. The school is equipped to give preliminary practical and theoretical training to apprentices upon their engagement at the age of fifteen years. After attending this preliminary training school for one year the boys enter the main carriage and wagon works to continue their apprenticeship.

Heavy Express Locomotive Trials on the Western Region

By O. S. NOCK, B.Sc., M.I.C.E., M.I.Mech.E., M.I.Loco.E.

No. I

In recent years some important alterations to the draughting arrangements of Western Region express locomotives have been made to enable them to cope with modern fuel conditions. Controlled road tests in 1953 *were followed by heavy load tests under service conditions in* 1955. *As a result, some further alterations have been made to the "King" class locomotives. In this article and a subsequent one, the author discusses the results of dynamometer car runs in* 1955 *and* 1956.

RAILWAY historians of the future will probably remark on the phenomenon that far more sustained research and study into the performance of the steam locomotive took place in the last few years of its life than at any other time. It was on the Paris–Orleans Railway that the first French change-over to main line electrification took place, and yet it was on that very line, and at roughly the same time as that changeover, that some of the most brilliant researches into steam locomotive working were made, by André Chapelon. In this country, the work of the Swindon and Rugby testing plants is providing the running departments with data as to locomotive capacity in a more precise form than was ever done before. Reference has already been made in THE ENGINEER to the severe tasks that will be set for the steam locomotive in its last years; from recent experience there seems little reason to doubt that the demands will be met, providing always that a reasonable standard of shed maintenance can be maintained during the transition years. So far as the "King" class 4–6–0 locomotives of the former Great Western Railway are concerned, the alterations to draughting, which yielded the improvement in performance recorded in THE ENGINEER for February 5, 1954, and February 12, 1954, put the maximum capacity of that class in advance of the best pre-war standards of running. It is indeed doubtful if one of them had ever previously been called upon for such high rates of continuous steaming with revenue-earning trains as was the case on the trial run of March 11, 1955. In any case, the effort on that occasion, and on other test runs in 1955 and 1956, was sustained for a far longer period than in the maximum-load controlled road tests of 1953.

With the prospect of the four-hour schedule between Paddington and Plymouth being restored in the summer of 1955, the trial runs in March of that year were arranged with the maximum mid-week load required by the operating department, on the proposed accelerated schedule. The tests conducted so far fall into three groups:

(*a*) March, 1955, with "King" class engine having improved draughting.

(*b*) April and May, 1955, with a "Pacific" locomotive of L.M. Region.

(*c*) May, 1956, with "King" class engine having twin-orifice blast pipe, double chimney and self-cleaning smokebox.

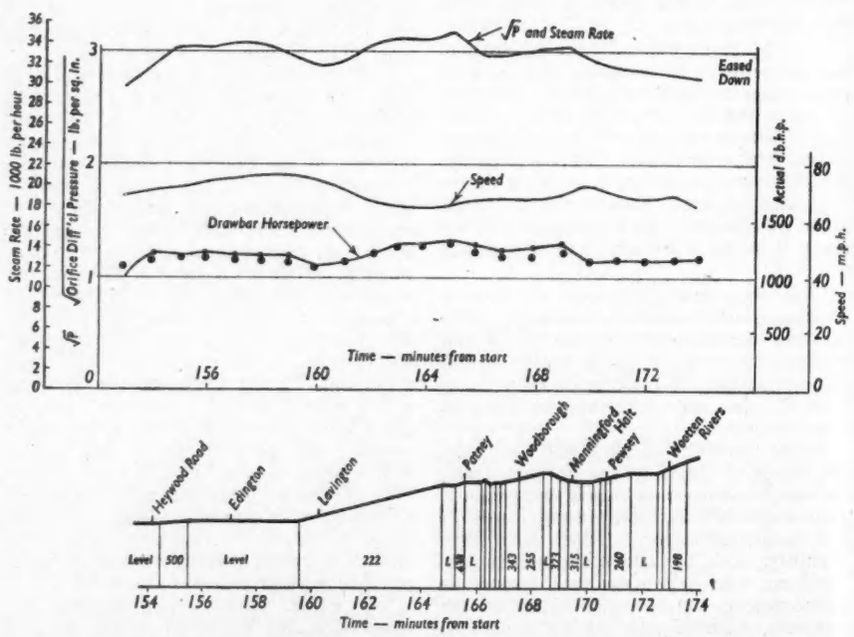
The tests in the third group, which extended to the Wolverhampton line in addition to the Paddington–Plymouth route, form a natural sequel to the 1955 series. The tests made in 1955 with both Western and London Midland Region locomotives were severe, in that several engineers' slacks for track repairs were in force, and an attempt was made in all cases to maintain the accelerated end-to-end schedules inclusive of all checks. With the "King" class engine on the first runs in each direction, while good work was done it was rather a case of taking the measure of the timing, and on account of the checks strict punctuality was not quite maintained. But on the third and fourth runs a deliberate attempt was made to see how much time was in hand with a locomotive worked at something near its full capacity.

There was, of course, a most important and significant difference between these trials and the controlled road tests described in THE ENGINEER for February 5 and 12, 1954. On the latter runs two firemen were carried; the coal was fed down in weighed bags of constant quality, and all conditions of running were very closely controlled. On the trials of March, 1955, with an ordinary service train, the driver and fireman booked to the duty had to carry out their normal duties; a locomotive inspector rode with them, and on the footplate there was also an observer, from the chief mechanical and electrical engineer's department, who was in constant telephonic communication with the dynamometer car. Four different crews were concerned on the four successive days, two from Old Oak Common depot and two from Laira, and it is very evident from the results that these men entered fully into the spirit of the tests and gave of their best. In other circumstances, the performance on the final day might be scarcely believable as a feat of hand firing by one man.

The preliminaries, before the reintroduction of the four-hour schedule of the "Cornish Riviera Express" in 1955, were made more interesting by the trial of a "Duchess" class "Pacific" engine from the London Midland Region. It is generally understood that the object of this further trial was to see if, in present running conditions, the much larger boiler and firebox of the 4–6–2 engine afforded any advantage, having regard to the different firing technique needed. In contrast to previous interchange locomotive trials of this kind, the visiting engine was worked by the regular "Cornish Riviera" link men. Prior to the actual test runs the engine, No. 46237, "City of Bristol," had been on loan to the Western Region for three weeks to give enginemen and running inspectors experience in handling her. It was considered that better representative results would be obtained with enginemen thoroughly familiar with the route and the duty, rather than with men familiar with the locomotive, but needing a road pilot. The West of England main line of the former Great Western Railway is, for most of its length, a difficult one to learn, and as things turned out the performance of the "Duchess" class engine in the hands of Western Region men was, for the most part, very fine.

Reverting now to the first group of trials, with a "King" class engine, it was my privilege to ride in the dynamometer car on March 10, while by the courtesy of Mr. R. A. Smeddle, chief mechanical and electrical engineer, British Railways, Western Region, I have been able to examine in detail the record taken on the very fine run made on the concluding day. The engine used, No. 6013, "King Henry VIII," was one of those selected for working the high-speed "Bristolian" express; it was built in 1927, but is now fitted with high-superheat boiler and improved draughting. At the time of the tests it had been out of the shops for five months since its last general overhaul; but while even more spectacular results might have been obtained with an engine newly out, the tests were more representative in being conducted with one somewhat below the highest standard.

The four-hour schedule to Plymouth involves an overall speed of 56·3 m.p.h., but such are the obstacles to fast running



Points plotted thus are calculated values at one minute intervals, based only on speed and steam rate

Fig. 1—Engine 6013 (single orifice blast pipe, improved draughting): load twelve coaches, 393·4 tons tare, wind 7½ m.p.h., north-easterly (adverse)

encountered at the western end of the journey that it is necessary to cover the 173·5 miles between Paddington and Exeter in 167¼ min, an average speed of 62 m.p.h. Although interest in the test results is naturally concentrated on the work east of Exeter, the circumstances that preclude any higher average speed than 43 m.p.h. over the remaining 52 miles of the journey are worth some notice, as the majority of them would affect the working of new diesel, or electric locomotives equally with steam. Due to curvature of the line, there are numerous speed restrictions, not on any one particular stretch, but occurring constantly, so that there is hardly time to recover speed from one before the next is approached. Furthermore, there is no opportunity of "rushing" the very severe gradients west of Newton Abbot, and the "King" class locomotives are limited to a maximum load of 360 tons over this section. With the maximum load of the "Cornish Riviera Express" on the four-hour timing, roughly 400 tons, a stop for an assistant engine is made at Newton Abbot, and the 43 m.p.h. timing between Exeter and Plymouth allows for this stop. On the basis of the established performance of the "King" class engines the locomotive testing office at Swindon has prepared running times for various loads and various rates of steaming, taking account of all permanent speed restrictions, but reckoning upon performance up to the stipulated rate of steaming intermittently. For a steam rate of 25,000 lb of steam per hour the following times have been calculated from a dead start at Plymouth (North Road) to passing Exeter, a distance of 52 miles :—

Load, tons tare ...	265 ...	360 ...	430 ...	500
Time, min	70 ...	73½ ...	72* ...	73½*

* With assistant engine to Newton Abbot.

In the case of trains requiring assistance the duration of the stop to detach at Newton Abbot must be added ; but, even so, it is evident that it is the speed restrictions rather than engine performance that largely govern the timing west of Exeter.

Paddington—Exeter Test Results

The experimental schedules were based upon a sustained evaporation of 25,000 lb per hour, steam to cylinders. This corresponds to a firing rate of roughly 3000 lb of coal per hour, but very early in the down run of March 10, 1955, it was evident that this target rate was being handsomely surpassed. Between Slough and Reading the steam rate was sustained at 28,000 lb and, despite a loss of about 2 min due to a permanent way slack at Reading West, the train was nearly 2½ min ahead of time at Savernake summit. Throughout the long gradual rise up the Kennet valley the steam rate had been held between 28,000 lb and 30,000 lb per hour. In pre-war years performance of this quality was approached in the working of the "Cornish Riviera Express," but generally speaking the effort was considerably eased after the first 100 miles of the journey. The schedule did not demand anything more. But on this trial run there was to be no "let-up," and on this account it was encouraging to see that a coal rate of more than 3500 lb per hour was being sustained in the early stages, rather than any husbanding of resources in view of the length of effort required. The possibility of a very high maximum speed descending from Savernake was ruled out by a second permanent way check, on the fastest stretch of all, near Lavington ; but nevertheless on passing Heywood Road Junction, and detaching the Weymouth slip portion, a distance of 94·6 miles had been covered in 91¼ min—roughly 87 min net.

Fig. 2—"Cornish Riviera Express" : "King" class locomotive with single orifice blast pipe, and improved draughting

It has sometimes been said that the practice of running at a constant rate of evaporation is impossible on all but a level or nearly level road. On this run there were, of course, times when steam was shut off, as in the descent of the Bruton bank and through Castle Cary, where there are speed restrictions ; but west of Castle Cary in particular, where speed varied, due to gradients, between a maximum of 84 m.p.h. and a minimum of 37 m.p.h., it was interesting to observe from the dynamometer car how nearly the driver's handling of the engine corresponded to constant evaporation working. There were no special test fittings in the cab ; the manipulations of the controls was left entirely to the driver's discretion. In the ascent of the Wellington bank, commenced at 70 m.p.h. and finished at 37 m.p.h., the evaporation rate lay entirely between 24,000 lb and 25,500 lb per hour. On passing Whiteball summit, 153·6 miles from Paddington, the train was 7½ min ahead of time, showing a net gain of 11½ min to 12 min, to engine on the proposed accelerated schedule. By Exeter nearly another minute had been gained. The time of 159¼ min to this point, 173·5 miles from the start, is, so far as can be traced, a record, by some considerable margin, for the West of England service by the old Great Western route.

Readings were taken from the integrator in the dynamometer car at various key points, and the following results give some impression of the effort required. The values are in all cases uncorrected for gradient :

Section	Distance, miles	Average d.h.p.
Southall to Strap Lane Halt...	99·2 ...	963
Southall to Cowley Bridge Junction	163·1 ...	875
Southcote Junction to Bedwyn (up Kennet valley)	28·5 ...	1150

After experiencing two further permanent way checks Newton Abbot, 193·7 miles, was reached in 186¼ min, 6¼ min early. The assistant engine provided for the heavily graded section of the South Devon line was a 4–6–0 of the "Castle" class, but the time in hand was expended on account of a severe slack at Totnes. The arrival at Plymouth was, however, in precisely 4 h from Paddington, despite some 12 min delay experienced en route. As regards the more exacting part of the journey from Paddington to Exeter, no difficulty was experienced in maintaining a high rate of steaming for more than 2½ h ; summary details of the engine performance between Paddington and Newton Abbot are as follows :—

Average net steam produced by boiler...	26,950 lb/hour
Firing rate	3,245 lb/hour
Average drawbar horsepower :	
Under power	978
Actual	828
Coal per drawbar horsepower hour :	
Inclusive of auxiliaries	3·32 lb
Exclusive of auxiliaries	3·21 lb
Average speed (actual)	62½ m.p.h.

On the return trip on the following day interest in the performance centres upon two factors; that between Newton Abbot and Paddington the train experienced a loss of 9 min due to temporary speed restrictions, and 1¼ min due to adverse signals ; and that an adverse wind was having the effect of increasing the resistance of the train. In a subsequent analysis made at Swindon the following values of the resistance were determined at various speeds and are tabulated alongside those of the down train on the previous day as between Paddington and Heywood Road :

From this it will be seen that the twelve-coach train of March 11 had approximately the same tractive resistance at the drawbar as the fourteen-coach train taken over the first half of the journey on the previous day. Naturally, such factors as adverse winds must be taken into account in the planning of train schedules that shall be practicable in everyday operation ; but with the incidence of the temporary speed restrictions in addition a severe task was set to the locomotive and crew in attempting to maintain the experimental accelerated schedule. Due to the earlier delays Exeter was passed 6 min late, but in spite of a further loss of 4 min by a

Wind and Rail Resistance of Coaching Stock

Run date	Load, tons tare	Wind	Resistance at drawbar, pounds			
			50 m.p.h.	60 m.p.h.	70 m.p.h.	80 m.p.h.
March 10, 1955	460	5 m.p.h., 45 deg. to tail	3,200	3,900	4,700	5,600
March 11, 1955	393·4	7½ m.p.h., 45 deg. to head	3,200	3,900	4,600	5,500

check at Castle Cary, there was time in hand for a punctual finish on passing Ealing Broadway, 5¾ miles out of Paddington. The concluding signal checks caused the arrival to be 1 min late.

The following summary is enough to indicate a performance of exceptional quality. The stretch between Exeter and Reading has been chosen particularly, as in the last stages of the run the fire was being worked down, and the overall figures would show figures for evaporation and coal consumption not entirely representative to the main effort of the journey, though more favourable to the locomotive.

Exeter–Reading

Running time	127·6 min
Average speed	64·7 m.p.h.
Power time	117·3 min
Total coal	8,240 lb
Firing rate	4,210 lb/hour
Net steam rate	29,835 lb/hour
Average drawbar horsepower	1,020
Coal per drawbar horsepower hour :	
Inclusive of auxiliaries	4·13 lb
Exclusive of auxiliaries	4·00 lb

These two runs serve to emphasise the manner in which performance of locomotives in general, and this class in particular, deteriorates in efficiency as high rates of evaporation are attained. The coal rates may be compared thus :

	March 10	March 11
Average drawbar horsepower	978	1,020
Steam rate, pounds per hour	26,950	29,835
Coal rate, pounds per hour	3,245	4,210
Coal per drawbar horsepower hour (exclusive of auxiliaries)	3·21	4·00

It is extremely interesting to note the close correspondence between the results obtained above on two runs with service trains and the basic performance recorded with the "King" class locomotives on the stationary testing plant at Swindon, in closely controlled conditions, namely :

Steam rate, lb/hour	Coal rate, lb/hour
26,000	3,200
30,000	4,065

With any performance of an exceptional nature, locomotive or otherwise, a close check and complete reconciliation of the results is desirable. In the locomotive testing office at Swindon, as usual, a very careful check was made on the performance of engine 6013 on the March 11 run. The accompanying diagram shows the result as related to a particularly interesting section of the journey. In this diagram, first of all, curve *A* shows the square root of the orifice differential pressure, to which quantity the steam rate is directly proportional. It will be seen at once that during this 24-mile stretch of adverse grading the steam rate was entirely above 30,000 lb per hour, rising at times to 34,000 lb—a remarkable feat of firing in itself. Over the 24·5 miles from Heywood Road Junction to Savernake, various steam rates give calculated times as follows :—

Steam rate, lb/hour	Time, min	Average speed, m.p.h.
25,000	23·5	62·6
28,700	21·9	67·1
31,500 (actual on test)	21·1	69·7

Reference to the gradient profile in the diagram is again enough to show what the maintenance of an average speed of almost 70 m.p.h. involves with a train of this magnitude, heading into an adverse wind.

On the diagram are plotted curves of the speed, on a time basis, and the actual drawbar horsepower. The check, and consequent reconciliation of results, is obtained by calculating the drawbar horsepower from the basic relations concerning the "King" class locomotives, as determined earlier in stationary tests and controlled road tests. The calculated drawbar horsepower values are based only upon the speed and the steam rate. Values have been calculated for conditions obtaining at 1 min intervals, and these values are plotted alongside the curve of actual drawbar horsepower. The correspondence is seen to be very close.

A point of considerable interest in this diagram, in view of subsequent developments at Swindon, is the curve of $\sqrt{P}$. This value was at times in excess of 3, corresponding to a back pressure of more than 9 lb per square inch. Earlier in the journey, while developing about 1100 d.h.p. at 75 m.p.h., the value was approximately 8 lb per square inch. At 900 to 1000 d.h.p. and a speed of 50 to 52 m.p.h. it was about 5 lb per square inch. The rise in back pressure, while enabling a high rate of steaming to be maintained, restricts the freedom of the locomotive at high speeds, and it was this feature of the "King" performance, in comparison with that of the L.M.R. "Duchess" class "Pacific," and with the "BR8" "Pacific" "Duke of Gloucester" that led to the Swindon investigation into double-chimney design.

Before leaving the test runs of March 10 and 11, 1955, however, tribute must be paid to the enginemen and the running inspectors who secured such an outstanding output of power from the locomotive under test, and so gave the testing staff of the Chief Mechanical and Electrical Engineer's department data of such interest and value.

(To be continued)

General Survey of the Ground Movement Problem

By PROFESSOR J. T. WHETTON

Ground movements due to mining have been under discussion this week at Leeds University, where an international conference on ground movements has been in progress. Here we print the introductory address given to the congress by the chairman of its organising committee.

IN this first European Congress on Ground Movement it is pertinent to review the subject briefly before any of the papers are presented. I appreciate that in making this survey there must necessarily be many gaps or omissions, and I apologise beforehand if the works of many of the ground movement experts present to-day are not expressly mentioned ; but it is impossible, within the space of a single paper, to give but an outline of the ground movement problem, and I hope that members present will make their own contributions to supplement what may be lacking.

In Great Britain, a Royal Commission was appointed in June, 1923, to report upon the consequences of mining subsidence from a number of different aspects. Part 2 of the *Minutes of Evidence* was concerned, among other things, with what was called the "basic laws of subsidence." To-day, most of that evidence would be very strongly contested. For example, assertions were made (*a*) that the angle of draw ranged from 5 deg. to 8 deg.; (*b*) that the extent of subsidence on the surface may be less than the extent of the underground excavation ; (*c*) that a critical change in surface behaviour exists when the dip of the seam reaches a value of 24 deg.

It is very noticeable in these *Minutes of Evidence* that there was no mention of lateral displacements and the derivative of surface displacement, namely, the straining of the surface. The omission is almost incomprehensible when one reads that as long ago as 1885 Mr. R. Stewart published records of lateral displacements to a maximum of 2ft 6in, resulting from the extraction of five seams whose total maximum amplitude of subsidence was 7·7ft. This neglect, or inability to recognise or appreciate, surface strains persisted in this country until the 1930s, when, in Scotland, Professor H. Briggs, in collaboration with Dr. W. Ferguson, devised a scheme for the measurement of the component. It is interesting to note that the Royal Commission on Mining Subsidence made a recommendation with a view to minimising surface damage. In effect, it proposed the use, where possible, of rapidly advancing longwall faces with special methods of packing. The evolution of methods of coal getting by the longwall system has been, as everyone knows, towards such rapidly advancing faces. The advantage to be gained from such faces in minimising surface damage is additional to the higher productivity that such systems bring. It is apparent, in the *Minutes of Evidence* of the Royal Commission of 1923 that any rules regarding subsidence behaviour were rudimentary and any field evidence was subject to large variations from the average expressed by the rules. There were, in any case, conflicting views among the principal witnesses.

The view that subsidence behaviour tended to be erratic and random in its behaviour was also held by Professor H. Briggs, whose book, *Mining Subsidence*, has been a standard work in Great Britain since it was first published in 1929. In his conclusions on the mechanism of subsidence, Briggs asserted that :

"Mining subsidence is not amenable to mathematical analysis and still less to mathematical synthesis. Empirical formulæ are sometimes useful as guides and will probably become more so as experience extends and is made more fully available, but, as things are at present, only the simplest rules are acceptable, and these should be received with ample reservations and applied with judgment."

That was fair comment at the time : it summed up the evidence of field investigators in different parts of the world which Briggs had collated and analysed in his book.

A Principle of Zone Calculation

Meanwhile, investigators in Germany and Holland were finding sufficient consistency in their surface measurements to justify an attempt to formulate rules wherein the magnitude of the subsidence effect could be predicted within reasonable practical limits of accuracy. A number of investigators developed a principle of zone calculation which had earlier been presented by Keinhorst in a simple form. The methods of zone calculation were then given publicity in Britain by Professor J. Sinclair and K. Wardell. The principle of zone calculation has been the foundation for observation, calculation and interpretation among many

Continental observers since Keinhorst first illustrated the principle. The basic premise in the method cannot be refuted as a generalisation. It is that the subsidence of a surface point, for flat measures, is conditioned by the extraction of a circular zone in each seam. The surface point under consideration is the centre of the circular zones. Complete extraction within the zone results in a maximum possible subsidence of the surface point. Partial extraction within the zone results in a partial subsidence of the surface point. Adherents of the principle have attempted to relate, quantitatively, the partial subsidence of the surface point to the magnitude and position of the partial areas of extraction. There are a number of difficulties in the application of the method for the precalculation of subsidence effects and particularly in the extension of the principle when inclined seams are being worked. But, implicit in the method, is the belief that the subsidence of a surface point is a function of :

(i) The seam thickness, the packing system and material used.

(ii) The depth of the seam.

(iii) The area worked, in magnitude and position, relative to the point.

(iv) The angle of draw.

(v) The inclination of the seam.

There can be no doubt that these factors are primary to the ground movement complex.

The terminology used in the zone method of calculation has been borrowed by British investigators. Such terms as "the subcritical," "critical" and "super-critical" areas of extraction are now understood, and are used, by British investigators. The zone method is a step towards the resolution of subsidence which investigators thought possible, and it is interesting to observe that such methods gave support to the possibility of the precalculation of subsidence effects. On the other hand, it is proper to note that, no matter how accurately the laws of subsidence may be formulated, there can be no clear guarantee that strata behaviour will, in every case, conform to the predicted rules. This can only be achieved when sufficient is known about the normal behaviour patterns to enable the abnormal to be separated from them. There are still a number of problems confronting the subsidence engineer, and it may be that some of the papers which are to be given before this congress will throw some light upon them. For example, there are six facets of subsidence about which, as yet, we know very little, and I think that as further information becomes available concerning them, our understanding of the mechanism of subsidence will become clearer. These facets are briefly commented upon under the following headings.

The Time Factor

It seems that there is a marked difference in the strata behaviour over shortwall faces and the behaviour over longwall faces. Developing curves of subsidence can be produced which show a rate which is substantially the same as the rate of advance of the face, which means that as mineral is removed subsidence takes place in volumetric magnitude comparable to that of the mineral being removed, less an amount depending on the type of packing. However, this effect does not start until a certain minimum area of coal is removed. In shortwall workings the area removed is always less than this minimum ; as a consequence the amount of subsidence on the surface bears no volumetric relationship to the amount of mineral extracted. The greater part of a coal seam may sometimes be extracted under circumstances where the roof beds are sufficiently strong to span the coal pillars without fracture or flow and the pillars are sufficiently resistant to support the overlying strata. A subsidence time factor for shortwall workings, as visualised, can therefore have no meaning. As long as the pillars retain their capacity to support, and the roof beds their capacity to span, the pillars, there can be no measurable subsidence. However, the potential subsidence under these circumstances is considerable and other workings in the vicinity may "trigger" subsidence, especially if the support equilibrium in the area of partial extraction is delicately poised. The time factor is thus, in some sense, connected with the area of excavation underground. It is also related to the depth of the workings. It is commonly considered that the cessation of subsidence follows very quickly upon the cessation of mining where the seams extracted are shallow, but the time for cessation of subsidence increases as the depth of the seams increase. But can the time factor, in respect of longwall workings, be expressed so simply ? It would appear that the continuance of subsidence as a post-mining effect has, at least, four possible roots :—

(i) Where the coal and/or floor is relatively soft, abutment pressures may cause yield over the support edges of unworked coal for some considerable time after mining has ceased. This effect may, indeed, be a function of depth since a greater pressure will be associated with the greater depth.

(ii) There may be gradual closure of the zones of incomplete convergence. This likelihood is again associated with the depth of the seam and the nature of the strata.

(iii) Where bed separation exists over a support edge, then there may be a gradual closure of the partings due to a time yield of the intermediate and surface beds.

(iv) Any change in the support condition in the goaf area may cause a further yield throughout the body of the overlying strata.

The times for the transmission of subsidence at different depths have been published for certain areas in Germany, but it is doubtful whether we have comparable information in Britain.

Related Subsidence/Convergence Curves

It is believed that the length, amplitude and shape of any curves of subsidence on the surface must, in some way, be related to the convergence curve which is found underground, but records of correlated subsidence/convergence curves are rarely found. There are a number of explanations why few investigators have attempted to measure both curves simultaneously, but I do not propose to discuss them now. However, it seems that when attempting to comprehend the mechanism of strata movements, the study of surface effects in isolation does not yield sufficient analytical material. At the level of the plane of excavation there are difficulties which do not present themselves when surface subsidence is measured. For example, it is not easy to distinguish between roof and floor movements or to determine bed separation ; it is rarely possible to measure the movement of the roof and floor ahead of the support edge. But I believe that a concerted attempt to relate surface and underground movements will throw considerable light upon the differences in subsidence behaviour which make themselves apparent.

One of the most fascinating and illusive features of subsidence is the so-called "angle of draw." The considerable variation in this value which has been measured by different observers is too wide to be attributed to mere observational discrepancies, and yet over British coal measures an angle of draw of some 35 deg. to 38 deg. repeats itself with a high measure of consistency. This angle is, of course, the rib side angle of draw ; over the face the angle of draw, again measured as a vertical angle from the line of the face, is invariably smaller. In addition, the dynamic strains over and in advance of the face are lower in magnitude than those which are to be found over the rib side. Having regard to the difference between the dynamic and the rib side angles of draw, a reduced angle of draw may be much more convenient to use, the reduced angle of draw being the angle measured from the point of half convergence underground to the limit of movement on the surface. Such an angle can only be obtained, however, if related subsidence/convergence curves are measured. It is interesting to note that the symbol γ_u is reserved for this angle in German subsidence terminology. It is defined as the angle of inclination of the line connecting the centre of the zone of incomplete convergence to the edge of the subsidence area. Another matter which is subject to some speculation is the true nature of what is tacitly accepted as the so-called "limit plane" or "limit line of movement." The limit plane is conjectured as a plane of demarcation. Outside this plane there is considered to be no induced movement. This conception is, in all probability, quite an erroneous one. It derives from the earliest interpretation of the word "draw" and is the simplest possible way in which the limit of measurable movement on the surface can be allied to the edge of the support zone underground. A far clearer picture is obtained when it becomes possible to draw lines of equal movement throughout the body of the overlying and underlying strata. In practice such measurements can only be made in roadways which lie above or below panels of extraction, and a great difficulty attending such measurements is the separation of the simple closure movements along these roadways from the movements which would be induced if the roadways did not exist. This problem is not peculiar to measurements of movement ; a similar difficulty exists in attempts which are made to measure strata pressure.

The Effect of Old Workings

When one studies published records of subsidence, it is very noticeable that curves of subsidence reproduce themselves with a high measure of consistency when nothing has been worked above the seam being extracted and the face advances at a uniform and fairly rapid rate. Where old workings exist above the plane of extraction, the effect of movement of the old workings is superimposed upon the normal subsidences. Thus it appears that the vertical movement induced may not differ very much, but the magnitude of the strain on the surface, both in position and direction, must be affected by the presence of old workings. It will be invaluable if records become available of the influences which old workings have upon the surface effect.

It has been shown that where a number of seams are being worked simultaneously, the interaction of one face upon another face or upon roadways in the other seams constitutes a major problem to the planning engineer in the layout and winning of such faces. The

presence of old workings is an additional variable and unpredictable factor.

Depth and Variety of the Superficial Deposits

Under favourable conditions, it is possible to obtain curves of strain on the surface which follow a pattern nearly as consistent as the subsidence pattern, but where unconsolidated deposits overlie the rock head, there may be a departure from consistency in the strains produced. Research is necessary into the differences that different types of unconsolidated deposits induce on the surface in the transmission of surface strains from bedrock to the surface.

The subsidence and strains that are found on the surface represent a boundary state. Their magnitude and distribution are the manifestations of a complex dynamic process which starts at the level of the plane of extraction. Much work has already been done by Dr. A. Winstanley and others in the determination of the differential movements in the roof beds overlying longwall faces. Methods similar to those used by Dr. Winstanley could be used to determine the development of subsidence and strains throughout the zones that constitute the upper bedrocks and the superficial deposits overlying the bedrock. The measuring stations would require careful design and a drilling pattern from the surface to the upper bedrocks devised to provide the requisite amount of information at a cost that would repay the effort.

Effects of Packing

Certain factors have been produced in the past which serve as a guide to the maximum subsidence which can be anticipated with different types of packing. For example, figures quoted for Germany are :

	Per cent
Solid pneumatic stowing	45—55
Solid mechanical stowing	45—55
Solid manual stowing	50—60
Dummy-road packing (Fläschenträger)	75—85
Dummy-road packing (Schulte)	58—74
Caving	85—95
Solid pneumatic stowing (Löffler)	55
Solid hand stowing (Löffler)	66
Caving (Löffler)	95

I consider the factor of depth is also pertinent to any estimate of the maximum subsidence possible for, say, a given seam thickness, and the nature and system of packing. It is self-evident, on a volumetric basis, that the degree of consolidation of the goaf affects the degree of subsidence. The degree of consolidation is in turn a function of the pressure developed over the goaf. The magnitude of that pressure depends upon the depth of the seam. There is also evidence that subsidence can be reduced in intensity at comparatively shallow depths because of the resistance offered by packs. Nor can we afford to ignore the initial convergence that occurs at a face before packs are built or the stowing material placed in position. The initial convergence may, sometimes, be as high as 30 per cent of the seam thickness. Thus, other things being equal, the speedier the insertion of the packing that follows coal extraction, the less will be the subsidence.

Effect from Inclined Seams

It is noteworthy that in the various methods that have been used, for the anticipation of the ground movement effect, the seams are usually assumed to be level, or nearly so. Such matters as the design of pillars of support, and the best layout of workings for the protection of surface property, become very difficult where the seams are inclined. The differences in pressure that are to be found due to the depth differential could result in a greater consolidation of packs on the dip side of faces. The result is a greater degree of vertical convergence at the greater depth, which has the effect of modifying the pattern of movements that are to be found over inclined workings. The criterion in this respect would appear to be the ratio of the depth on the dip side of a longwall face to that on the rise side. This ratio is unity for level, or nearly level, seams at all depths. But the ratio for inclined seams depends, not only upon the inclination of the seam, but also upon the magnitude of the depths of workings on the rise and dip sides. This ratio, for a given seam inclination and face width, departs more and more from unity as the seam becomes shallower. Consequently, at very shallow depths there is a marked difference in the subsidence effect over the rise and dip sides of faces. However, at considerable depths, the effect of seam inclination is not so clearly seen, since the trough of subsidence which is produced resembles more closely that of the level seam. There is still a considerable amount of field research possible where the opportunity exists to take observations over semi-steep and steep seams.

Conclusion

The six points listed in the preceding cross-headings appear to be vital in any expansion of investigations of subsidence behaviour. When subsidence records are published a history of the working area should also be published, complete in regard to plans, sections and geology of the area. Merely to publish the curve of vertical movement in isolation serves no useful purpose, since comparison and relation to any other type of subsidence curve cannot be made unless details of the depth of the seam, thickness of the seam, type of packing, position of measurement, layout of the face, type of strata, &c., is published with the curve.

It becomes apparent when studying the work of earlier investigators that the diversity in methods of working, absence or the ignoring of data relating to previous workings, differences in strata type and structure and the lack of conformity in methods of field measurement have been partially responsible for the view that rock movement cannot be rationalised. Modern methods of longwall workings make for greater simplicity in layout, but it would be wrong to assume that this always enables accurate prediction to be made of the surface effects. Early investigators were at pains to limit the behaviour of undermined strata within a single all-embracing "theory." Most of these theories, in the light of present knowledge, can be discounted, and modern investigators are careful to avoid the pitfall wherein generalisations are made from field measurements taken almost in isolation. It is, however, just as misleading to say that there is no common thread in the movement behaviour over longwall faces of different dimensional and geological character as it is to say that all behaviour patterns can be integrated into one set of laws. As field observations increase in number and variety, it is reasonable to anticipate that certain well-defined laws will appear. It is possible that these may be facilitated by the exchange of information and discussion in congresses of the type we are holding now.

Lloyd's Wreck Returns.—The totals of merchant ships totally lost, broken up, &c., during the quarter ended September 30, 1956, have been published by Lloyd's Register of Shipping. A total of thirty-three steamships and motorships of 78,687 tons gross were lost consequent upon casualty throughout the world, and included five ships of 9920 tons owned in Great Britain and Northern Ireland. The corresponding returns for ships broken up, &c., are seventy-six ships of 104,525 tons gross and forty-seven ships of 19,774 tons.

Advances in Aircraft Bonding

Last week a conference on Bonded Aircraft Structures was held by Aero Research, Ltd., at Cambridge, and attended by engineers of many nationalities. Papers were presented by, among others, representatives of Chance Vought, Fairchild, Fokker, S.A.A.B., and Ouest Aviation. On the Thursday delegates flew to Filton to inspect the bonding and other production departments of Bristol Aircraft, Ltd., and on the following day visited Aero Research, Ltd., Duxford, to tour the factory and see a display of bonded components and test apparatus.

Included in the display were demonstrations of the forming of honeycomb core to aerofoil sections by filling it with wax and shaping with a woodworking plane. Since traces of wax are incompatible with "Redux" bonding, the preferred technique is to fill with "Araldite" 6100, without hardener, which can be melted out at 110 deg.–120 deg. Cent.

For applying heat to curved panels when bonding, a conducting fabric known as "Mhoglas," produced by A. J. Kemp and Son, Ltd., Harlow, Essex, was shown. This consists of glass fibres coated with graphite, woven into cloth, and treated with resin to form a light, flexible cloth which does not unravel and which can be handled when at a potential of 240V. While it can be used as a heating element in the form of a cloth, it was demonstrated as an inset in an "Araldite" mould ; such moulds have proved satisfactory up to 150 deg. to 160 deg. Cent. under pressures of 100lb.–200 lb per square inch.

There were demonstrated four devices under development for testing the integrity of the bond between a skin and a honeycomb core. The Fokker Bond Tester fed a sonic oscillation into the skin at one point ; a probe was traversed over the remainder of the sheet, oil having been interposed to obtain uniform coupling. Areas in which the bond was lacking showed a low energy level. A method originated by Aero Research was to heat the panel at one point and measure the thermal response at two nearby points. The remaining two techniques detected deflection of the skin when atmospheric pressure was removed from one side.

To enable bonding to be used in structures subjected to some degree of kinetic heating, there have now been developed the "Hidux" resins. Adhesives 952 and 967 are based on superpolyamides (Nylon) and phenol formaldehyde ; they are claimed to have a satisfactory hot strength up to temperatures of 150 deg. Cent. and 180 deg. Cent., respectively. The shear and peel strengths are similar to those of "Redux" except that 952 is superior in peel. These resins have extremely short curing cycles, four minutes at 185 deg. Cent. and two minutes at 220 deg. Cent., respectively, and in fixtures designed for rapid heating and cooling, bonding can be completed in about five minutes ; only nominal pressures are needed.

"Hidux" 1033 is, like "Araldite," an epoxy resin ; the performance of both 967 and 1033 in relation to the relevant United States Air Force Specification is shown in the accompanying table. "Hidux" 967 has passed with a large margin all the fluid immersion tests specified.

Performance of "Hidux" in Relation to U.S.A.F. Specification Mil-A-8431 Type I

	Specification requirements	"Hidux" 967	"Hidux" 1033
Normal temperature shear strength	2250 p.s.i.	5000 p.s.i.	—
300 deg. Fah. shear strength	2000 p.s.i.	2950 p.s.i.	2600 p.s.i.
−67 deg. Fah. shear strength	2250 p.s.i.	4960 p.s.i.	—
Normal temperature fatigue strength at 10,000,000 cycles	600 p.s.i.	800 p.s.i.	Over 800 p.s.i.
Normal temperature creep-rupture	1600 p.s.i.	2500 p.s.i.	2000 p.s.i.
Strength and deformation for 200 hours	0·015in max. total deformation	No creep	No creep
300 deg. Fah. creep-rupture strength and deformation for 200 hours	800 p.s.i., 0·015in max. total deformation	900 p.s.i. No creep	1000 p.s.i. No creep
Normal temperature bend strength	130 lb minimum load	280 lb	160 lb

275kV System of the Central Electricity Authority*

By F. J. LANE, O.B.E., M.Sc., M.I.E.E.†

This paper has attempted to outline the main characteristics of the 275kV system and its associated equipment now under construction in the United Kingdom. As the author points out, certain minor difficulties have been experienced, but they are no more than would be expected where the general plan and the associated equipment are on so large a scale, not hitherto tried in service. Present experience points to the successful establishment of a system which will meet the expanding needs of the country in terms of load and generating plant for some years to come.

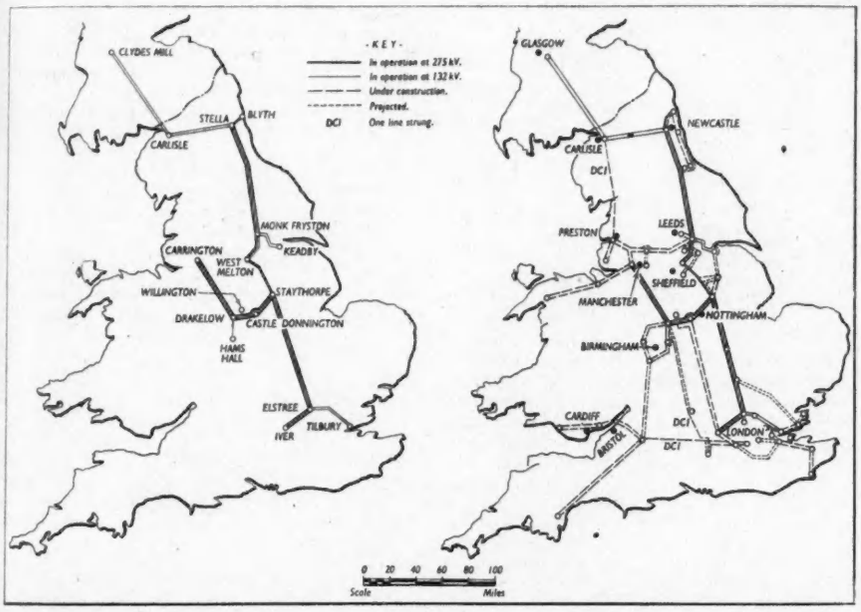
INCLUDED in the programme of work completed by the Central Electricity Authority in England and Wales during 1956 were 511 circuit miles of 275kV overhead line, thirty-five 275kV circuit breakers, and twenty 275/132kV, 120MVA auto-transformers. Thus, for the first time, an appreciable portion of the British 275kV system was brought into operation and the plan which had been prepared in 1950 began to take definite shape and to aid the improvement of supply system operating conditions in Britain.

The outline of the 275kV system as completed up to the end of 1956 is illustrated in the first diagram, and for comparison the second diagram is included to illustrate the expected development of the system up to 1965.

The 132kV grid, extending from the South Coast of England to Glasgow and Dundee in Scotland, has operated as a completely interconnected network since 1939, but even before the end of the war it was clear that if expanded at this voltage to keep pace with peacetime development it would rapidly become too complicated to operate as one system and to obtain the economies resulting from national operation. Some preliminary thought was given to future requirements, and experimental work was initiated into the characteristics of higher voltage conductors and insulators.

When the industry was nationalised in 1948 one urgent necessity was the establishment of an outline design of the transmission system on which it would be possible to plan the extensions necessary to meet future supply requirements. With a maximum demand in 1950 of the order of 12,500MW it was decided to develop a plan suitable for an increase of this figure to 30,000MW during the next fifteen to twenty years and to start the construction of a definite scheme capable of meeting requirements up to 1960.

This voltage (275kV) was chosen as being the highest standard voltage for which lines and equipment could be reliably designed and constructed for operation in the varied atmospheric conditions of the British Isles. Although the use of 380kV in Sweden and Germany was noted, there was some feeling that in British climatic conditions the performance of outdoor insulation would become more difficult in this higher voltage region. The need for the new system was then so urgent that the possibility of constructing reliable equipment within five years had to take precedence over the desire to follow closely but more carefully and slowly on the heels of the most advanced technical experience.



Maps showing the Central Electricity Authority's 275kV system (left) in December, 1956, (right) in 1965

The functions of the new 275kV system are :

(*a*) To pool the generating plant, i.e. to minimise the amount of spare plant required by providing such interconnection capacity between the areas of the country as will enable the installed generating plant to be used to its maximum extent wherever it may be, to cover variations in generation and demand which cannot be forecast, such as those resulting from delayed completion of generating plant, inaccurate load estimates, local fuel difficulties, &c.

(*b*) To facilitate the location of generating plant near the coal-producing areas, so that energy can be transmitted as electricity by overhead line in preference to the more expensive transport of coal long distances overland to generating stations sited near the load centres.

Practical experience and technical assessment had provided data from which the capacity of the connection to meet the pooling requirement could be determined, and the initial design of the 275kV system was prepared on the basis that the generating plant would be located as near as possible to the load centres, with proper regard for fuel and cooling water requirements. Economic assessments showed that an interconnection (pooling) system to meet requirements up to 1960 could be provided at a cost of £64,000,000, and that this, by permitting the reduction of spare generating plant otherwise necessary in the various areas, would reduce the capital expenditure on generation and certain transmission works by at least £110 million in the same period. If such an interconnected system were also to be used for economic transfers of energy from generating stations sited on the coalfields to load areas such as the London area, then additional overhead line capacity would be required ; this might be provided by means of overhead lines having larger conductors than those in the first plan or by additional overhead line circuits. The extra cost for this additional provision would be about £8,000,000, but there would be operational savings rising to £5,000,000 per annum.

The major developing coalfields are those in the Midlands and Yorkshire from which heavy transport of energy, either as coal or as electricity, will be necessary to the North West (Manchester and Liverpool) areas and to the South East and South West (London and Bristol). In the adopted plan, therefore, it was decided to provide 275kV lines of 375MW per circuit from Yorkshire up to Scotland, where interconnection was the main consideration, and lines having a capacity of 550MW per circuit at 275kV between Yorkshire, the Midlands and the southern part of the country.

Overhead Lines

Prior to 1948 the Central Electricity Board had decided to build an experimental single-circuit overhead line about 42 miles in length between Staythorpe (Newark) and West Melton (Sheffield) in the Midlands. This line was of single-circuit construction with the conductors in flat formation spaced at 31ft 6in between phase centres, each phase having two steel-cored aluminium conductors of 0·175 square inch copper equivalent cross section, 12in apart. This line was under construction while the new plan was being considered, and it was officially commissioned in July, 1953. The work associated with this initial design naturally provided a very useful basis for the later designs, but one important departure was considered to be necessary, in that in so small a country as Great Britain it would be essential to make the maximum use of any line route that could be obtained, and consequently double-circuit construction must be adopted. Thus, apart from the single-circuit line mentioned, all other 275kV lines in Britain use line supports of the double-circuit pattern, although on certain routes only one circuit is strung for the present.

For the lines from Yorkshire northwards the twin 0·175 square inch conductor arrangement was adopted, and for those from Yorkshire southwards and westwards the conductors used are twin 0·4 square inch copper equivalent. It is possible that the cost of the former could have been reduced by using a single 0·45 square inch conductor, but there are advantages in current carrying capacity and line reactance, and these, considered with the research data available, were felt to justify the choice of the twin conductor. The twin 0·4 square inch conductor at 12in spacing could, as a conductor arrangement, be increased in voltage to 380kV without dangerous increase in corona or interference levels. The electrical characteristics of the two types of line are shown in the following table in company with the characteristics of the standard 132kV lines :—

TABLE I—*132kV and 275kV Overhead Line Characteristics*

Voltage, kV	Conductor in Cu. equivalent, square inches	Resistance, ohms/mile	Reactance, ohms/mile	Charging current, amps/mile
275	2×0·175	0·125	0·54	0·94
275	2×0·4	0·055	0·53	0·94
132	0·175	0·24	0·66	0·36
132	0·4	0·11	0·65	0·36

* Abstract of paper at Nineteenth Annual Meeting of American Power Conference, Chicago, March 27-29, 1957.

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The thermal ratings of the conductors for a temperature rise of 30 deg. Cent. on an ambient temperature of 20 deg. Cent. are as follows :—

TABLE II—*Current Ratings*

Voltage, kV	Conductor in Cu. equivalent	Current rating, amps.	Capacity, MVA
132	0·175	400	91·5
—	0·4	600	137
275	2×0·175	800	381
—	2×0·4	1200	572

The line supports or towers are of galvanised steel lattice with concrete block foundations and the insulators are cap and pin type of either toughened glass or porcelain. The minimum ground clearance of the conductors for the twin 0·175 square inch line is 23ft, but where there is a possibility that the future operating voltage may be 380kV this ground clearance is increased to 25ft. The normal span length is 1200ft. The basic factors controlling design are specified in Government regulations. For steel supports the factor of safety under assumed maximum working loadings is 2·5, based on the elastic limit, and the safety factor for conductors is 2, based on ultimate strength. The conductor loadings specified in the regulations are those obtained with the conductor coated with ½in radial ice and subjected to a wind of 50 m.p.h., but the Authority introduce a further safety factor by assuming a radial ice thickness of ½in.

It seemed desirable to make some provision for later 380kV operation, but it would have been quite uneconomic to provide tower designs of such dimensions that clearances in air and accommodation for insulator string length would be adequate for 380kV working. It was felt, however, that no lines would be required for commercial operation at 380kV within the next ten years and there seemed some prospect that within that period designs of outdoor insulators would be so much improved that by the time they were required it would be possible to obtain adequate insulation for 380kV in the space initially required for 275kV working. The basic design of 275kV, 2×0·4 square inch conductor line therefore includes electrical clearances which are adequate for 380kV, but provides for a conventional insulator string length suitable for 275kV working only.

The insulator units used for suspension strings are of the "fog" type, i.e. they have a deep skirt, which increases the leakage path and improves the performance under polluted atmospheric conditions. It is a normal requirement of the Authority to specify a leakage path of 1in per kilovolt, of which 0·6in is protected. A typical suspension string for 275kV working includes eighteen units giving an overall leakage path of 300in and a protected leakage path of 180in. Porcelain and toughened glass insulators are widely used and there is no technical discrimination between the two types.

The service period is too short to admit of much comment on experience. Certain designs of line spacer showed serious signs of failure even before the lines had been made alive and some extensive replacement programmes have been necessary. There were eight lightning faults on the 275kV overhead lines during 1956 ; damage was so slight as to be impossible to find in some instances.

Investigations are proceeding into the possibilities of applying insulation suitable for 380kV working, and it certainly appears desirable that where, as in the case of tension insulators and post and bushing insulators the physical restriction will not apply, the leakage path should not be less than 380in, 50 per cent protected. For the suspension insulators twenty-one units of the "anti-fog" type should be satisfactory in clean or slightly polluted areas, but in those polluted areas where trouble is likely to be experienced in service it will be necessary to coat the surface with a suitable grease, renewable according to experience, but possibly not more than once every two years. No final conclusions have yet been reached, but a definite project is under consideration for increasing the working voltage of a line to 380kV so that experience can be obtained in varied atmospheric conditions.

Radio and television interference are not serious problems because of the comparatively high field strengths of the programmes concerned. Tests have indicated that the lines compare very favourably with lines of similar construction and voltage in other countries.

TRANSFORMERS

The 275kV system is earthed solidly at every transformer neutral point, and in view of the ratio of transformation from the 132kV system there are definite capital savings in making use of star-connected auto-transformers with delta-connected tertiary. Transmission distances in Britain are not great and, consequently, a high reactance does not seriously prejudice stability. A high reactance, moreover, assists in restricting the short-circuit duty at the substations and thus keeps down the associated switchgear costs. A reactance of 15 per cent was specified for the 275/132kV auto-transformers at the normal ratio.

Flexibility of voltage control as between the 275kV and 132kV systems was considered to be essential, but, whereas in the early stages series boosters were thought to be necessary for this purpose, subsequent developments have made possible and economic the provision of on-load tap changing as described later.

Double-winding transformers are necessary as generator transformers and where connection from the 275kV system is required to some other system at a voltage lower than 132kV. All windings rated for 275kV have graded insulation, with insulation at the neutral end of the windings equivalent to 22kV. The windings are designed for impulse withstand level of 1050kV peak, the specified test including the application of chopped waves with an applied wave having a peak 15 per cent above the specified full-wave withstand level.

132kV transformer bushings have been dimensionally standardised for some years, and early steps were taken to standardise the 275kV bushing similarly. These bushings have an under-oil configuration of a re-entrant form. They are supplied by manufacturers using different basic designs, e.g. oil-impregnated paper and synthetic resin bonded paper and include an earth band 16½in long for protective current transformer accommodation.

All the 275kV transmission transformers are provided with forced-oil, air-blast cooling (OFB). The rating is so specified that 50 per cent of the continuous maximum rating is obtainable under natural cooling conditions, e.g. a 120MVA transformer would be specified as 60/120 OFB, the cooling radiators being supplied as separately mounted banks in two sections, each section complete with its own oil pump and fans, having a capacity equivalent to 50 per cent of the transformer rating.

The auto-transformers are provided with on-load voltage regulating equipment covering a range of ±15 per cent on 132kV which can be provided by one of the following methods :—

(*a*) Tappings at the 132kV point covering the full range.

(*b*) Tappings at the neutral end covering the full range.

(*c*) Tappings at the neutral end covering an on-load range of ±10 per cent with "off-circuit" biasing tappings at the 132kV point for ±5 per cent.

Method (*a*) involves insulating the tapping connections for 76kV-to-earth working and the diverter switches are therefore housed on a porcelain support which provides the 132kV termination to the winding. Whilst the same voltage problem does not arise with method (*b*) the auto-connection makes necessary a larger transformer to give the same voltage variation. Method (*c*) permits alternative on-load variation of +5 to −15 per cent or +15 to −5 per cent, and its application is limited to situations where the power flow is uni-directional. Transformers using method (*a*) have incorporated high-speed resistance tap changers, whereas for methods (*b*) and (*c*) the tap changers are of the reactor type.

All auto-transformers so far made are core type, built from hot rolled steel. The choice of three-limb and five-limb construction is left to the discretion of the manufacturer, who also decides whether to use disc, or multi-layer concentric, windings. A maximum flux density of 13,000 lines per square centimetre at normal ratio is specified with a limit of 15,300 lines per square centimetre on any tapping position with a maximum on-load terminal voltage of 300kV, to take account of the large variation that can occur with the tapping range specified and the auto-connection.

The neutral end of each phase of the main winding is brought out to a separate bushing to permit the installation of protective current transformers in each phase of the earthed star point. A delta-connected tertiary winding for harmonic suppression is also provided, two leads from one corner of the delta being brought out to separate bushings so that the delta can be completed external to the tank for test purposes. The tertiary winding is earthed by connection to one of the neutral phase end bushings on the winding side of the protective current transformers, so as to provide earth fault protection.

With the voltage ratio and tapping range specified either the series or common part of the winding can provide the thermal limit depending on the tapping switch position and therefore "thermal images" feeding the winding temperature indicators are associated with both parts of the winding, using current transformers mounted on the 275kV bushing and in the neutral lead respectively.

Whilst tapping arrangements (*b*) and (*c*) should lead to a heavier transformer than arrangement (*a*), the various forms of construction, i.e. core and winding design, clamping structure and tank, adopted by different manufacturers, result in a greater weight variation than that arising from the choice of tapping arrangement. Typical weights and oil quantities are as follows :— Transport (without oil), varying from 110 to 130 tons ; total installed weight, varying from 210 to 260 tons ; total oil quantity, varying from 18,000 to 25,000 gallons. The total weight and oil quantity depends on the tank design adopted ; contour designs have recently shown considerable reduction.

Losses guaranteed at the normal ratio appropriate to the different tapping arrangements are as follows :—

	Arrangement (*a*)	Arrangement (*b*)	Arrangement (*c*)
Iron loss	129kW	116kW	116kW
Cooler loss ...	29kW	29kW	29kW
Copper loss ...	497kW	521kW	527kW

Double-wound transformers are used to give a bulk supply to lower voltage networks, but they have so far been confined to the rating of 120MVA with a ratio of 275/66kV. Specified characteristics are as follows :—

(i) On-load tapping range of ±15 per cent provided by equipment at the neutral end of the 275kV winding.

(ii) Impedance at normal ratio 20 per cent.

(iii) Connections star/star (with delta connected tertiary winding for harmonic suppression rated at one-third the capacity of the main windings).

(iv) Impulse withstand level for the 66kV winding, 350kVp.

The guaranteed losses at normal ratio are : iron 225kW, copper 720kW and cooler 45kW. Typical weights and oil quantities are : transport (without oil), 165 tons ; total installed weight, 300 tons ; total oil quantity, 21,600 gallons.

Generator transformer ratings so far adopted are 106MVA, 125MVA and 210MVA, associated with 100MW, 120MW and 200MW machines. The voltage ratio specified is 13kV to 16kV (depending on the output voltage of the machine), to 295kV, with a tapping range of ±10 per cent provided by equipment at the neutral end of the 295kV winding. The l.v. windings are connected in delta and the h.v. windings in star. The impedance value specified for the 106MVA and 125MVA is 17½ per cent and for the 210MVA approximately 15 per cent, subject in the latter case to a maximum impedance of 17 per cent on any tapping position.

Oil forced water cooling (OFW) is adopted as standard, provided in the form of either two 100 per cent or three 50 per cent coolers to enable cleaning of the oil/water heat exchangers

with the transformer carrying rated load. Guaranteed loss values for the different ratings are given in the following table :—

TABLE III—*275kV Generator Transformer Losses (kW)*

Rating	106MVA	125MVA	210MVA
Iron loss	190	205	280
Cooler loss ...	20	23	20
Copper loss ...	590	700	940

Typical weights and oil quantities for the 210MVA size (based on cold reduced grain oriented steel at a flux density of 16,000 lines per square centimetre) are : transport without oil varying from 150–160 tons ; total installed weight varying from 230–260 tons ; total oil quantity varying from 16,000–20,000 gallons.

INSULATION LEVELS

It has not been the practice of the Central Electricity Authority or of the Central Electricity Board, who preceded them, to employ lightning arresters on the 132kV system except for generator-transformers stepping direct up to 132kV and for transformers at the remote end of wood pole lines without earth wire. Experience has shown that simple co-ordinating gaps at the 132kV terminals of the transformers provide adequate and economic protection and, moreover, introduce a smaller fault risk than would be present with the universal use of lightning arresters. This same policy will be followed for the 275kV system and designs of 275kV lightning arresters are being considered and tested.

The following Table IV gives comparative basic insulation data applicable to 132kV and 275kV substation overhead lines :—

TABLE IV—*Basic Insulation Data*

	132kV	275kV
Substation equipment		
Nominal system voltage... ...	132kV	275kV
Highest system voltage	145kV	300kV
Neutral earthing	Solid earthing at each transformer	Solid earthing at each transformer
Basic impulse voltage	550kV for transformers	1050kV
Withstand	650kV for other substation equipment	—
Power frequency dry withstand voltage (1 minute)	300kV	485kV
Power frequency wet withstand voltage (30 seconds)	285kV	460kV
Power frequency dry momentary withstand voltage	355kV	575kV
Power frequency under oil or puncture voltage	410kV	660kV
Total external creepage distance	132in	275in
Protected creepage distance ...	66in	137in
Minimum clearance in air to ground	50in	84in
Minimum clearance in air between phases or poles of the same phase	58in	98in
Safety clearance	11ft 6in	15ft 0in
Surge protective co-ordinating gaps	26in	46in–52in
Arcing gaps in general	39in	75in
Overhead lines		
Nominal system voltage... ...	132kV	275kV
Actual impulse strength of insulator without arcing gaps	In excess of 750kV	In excess of 1500kV
Clearances :		
With insulator vertical ...	50in	90in
With insulator deflected 5 deg.	—	86in
With insulator deflected 30 deg.	46in	54in
Arcing gap setting for :		
First mile	39in	75in
In open country	44in	No figure specified as horns are on the live side only

As already mentioned, for 275kV lines which may later operate at 380kV the only provision made for this higher voltage working is in the increased clearances between conductors and the tower members. For example, with the twin 0·4 square inch design the electrical clearance with insulator vertical is increased to 135in and with the insulator string deflected by 30 deg., to 85in.

Earthing conditions are good throughout the system. It is rare for a tower footing resistance to exceed 20 ohms.

SUBSTATIONS

The design of structures is based on the requirement that no such structure should fail (in adverse weather conditions) until after the overhead line supports associated with the substation have failed. Table V, which follows, compares the data used in designing overhead line towers and substation structures :—

TABLE V—*Data Used in Designing Overhead Line Towers and Substation Structures*

	Overhead line towers	Substation structures
Radial ice on conductors ...	½in	½in
Temperature range of conductors	22 deg. Fah. to 122 deg. Fah.	22 deg. Fah. to 122 deg. Fah.
Wind velocity	60 m.p.h.	85 m.p.h.
Maximum conductor tension, 132kV	—	1,000 lb per phase
Maximum conductor tension, 275kV	—	3,000 lb per phase
Working stress in mild steel reinforcement	—	18,000 lb per square inch
Working stress in 1 : 2 : 4 concrete	—	1,100 lb per square inch
Factor of safety (unbroken conductor condition)	2·5	2·0
Factor of safety (broken conductor condition)	1·5	
Relative strengths of towers and structure, approximate	100 per cent	125 per cent

The two kinds of supporting structure most widely used for substation equipment are the reinforced concrete structure and the structure formed of bolted galvanised rolled steel angles. For the new 275kV substations reinforced concrete structures have been used throughout because they are slightly cheaper to construct and if properly made involve practically no maintenance cost. They may be precast on site or cast in situ, but the former is preferred as being a little cheaper and providing a better finish.

The most usual substation layout is of the double busbar pattern, although in one or two instances where special conditions apply a mesh type or three-switch type has been employed.

It was natural that in embarking on such a large scheme as the 275kV scheme, some serious consideration should be given to the possibility of switchgear standardisation. No progress was made in this direction with the circuit breakers but a standard design of two-post isolator has been produced by three of the manufacturers and used universally, and interchangeable designs of current and voltage transformers are used.

The isolators are designed for one rating only, namely, 1200A, 7500MVA. Each phase comprises two contra-rotating eight-unit insulator stacks, to the upper ends of which are fixed contact arms operating in the horizontal plane. The contacts are of the double-sphere and spade type, which give four high-pressure contact points, with contact pressure adjustable by means of a spring strained between the twin arms carrying the double-sphere contacts. Each line connection is made to a helmet which rotates on a ball race inside the top fitting of each insulator stack and flexible connections are made between the helmet and the inside of the top fitting which, in turn, carries the contact arm.

The three phases are mechanically coupled to each other and to a vertical torque tube on the centre phase which is driven by the common operating mechanism. The mechanism comprises a closed oil-hydraulic system in which a reversible motor-operated pump drives a double-ended piston.

CIRCUIT BREAKERS

Four different designs of circuit breaker are at present employed, three being air-blast and one bulk oil. The standard short-circuit rating is 7500MVA and there are two continuous current ratings—800A and 1200A. All 275kV circuit breakers have a 1/50 impulse voltage withstand level of 1050kV and a one-minute power frequency withstand level of 485kV.

The bulk-oil breaker has three lenticular tanks with four series-interrupters per phase, each interrupter being fitted with a non-inductive wire-wound switching resistance. Spring-loaded oil-barrier bushings each support two interrupters at their lower ends. The fixed contacts are multi-finger butt contacts engaging with flat-topped moving rods. The pneumatic, mechanically trip-free, closing mechanism operates all three phases by push-pull rods. Opening is effected by means of torsion accelerating springs. Air pressure for closing is 325 lb per square inch and the unit receivers contain enough air for at least two closing operations. The oil volume of the breaker is approximately 2000 gallons per phase.

Two of the air-blast breakers supplied have six series-interrupters per phase, one using one blast valve for each two interrupters, and the other one blast valve for each three interrupters. The third design has eight interrupters with one blast valve for each four interrupters. These breakers incorporate integral series isolators, and have their air receivers at earth potential as part of their base structures. Interrupters are of the axial blast type, the moving contacts being spring returned and normally closed. Equal voltage distribution is obtained either by " Bakelized " paper condenser tubes built into the interrupters or by externally mounted porcelain-clad resistances of the linear or non-linear silica carbide type.

Each phase has its own electro-pneumatic operating mechanism but the individual mechanisms are electrically and pneumatically interconnected to give simultaneous three-phase operation. As for the oil-breaker, the operating pressure is approximately 325 lb per square inch, with sufficient storage in local receivers for two " make-break " operations. The breakers all comply with B.S. 116 : 1952, where applicable. The Authority has insisted on a rigorous and extensive works testing programme, agreed with the individual manufacturers and modified where necessary to take account of differences in design. These programmes have ensured very careful attention to detail at all stages and a very thorough knowledge of the performance characteristics. Short-circuit tests have not been carried out on the system, principally because it is the Authority's belief that such tests cannot be generally representative, neither are they sufficiently severe to cover system developments likely to take place during the service life of the circuit breakers. However, certain special tests, such as line dropping and magnetising current tests, have been made at one substation.

The total break-time of any 275kV breaker does not exceed 0·1 second on any breaking capacity test duty specified in the above British Standard. The total break-time of the bulk-oil circuit breaker is 0·065 second with an opening time of approximately 0·03 second, and one air-blast circuit breaker has a total break-time not exceeding 0·085 second. The breakers are suitable for the addition of high-speed automatic reclosing facilities with a circuit dead time adjustable down to 0·25 second, but automatic reclosing has not as yet been applied in service.

The operating air is stored at a pressure not exceeding 650 lb per square inch and reduction in humidity of the operating air is obtained by expansion only from storage pressure down to operating pressure.

The principal forms of protective equipment employed include high-speed phase-comparison equipment with an operating time not more than three half-cycles, for the main feeders, balanced-current protection and Buchholz protection for the transformer feeders, and balanced earth-fault protection for the main busbars. For the transformer feeders remote tripping equipment may be necessary, either carrier-current or a design using Post Office communication channels.

CABLES

There are no 275kV cables in commercial service at present but, based on 132kV experience, five designs are in process of development and testing. In order to obtain service experience a testing station was established at Staythorpe in 1954 and there are at present four of the designs on test there. They include: (*a*) a low-pressure oil-filled, single-core cable with maximum electrical stress of 110kV per centimetre ; (*b*) a single-core impregnated gas-filled cable with a maximum stress of 110kV per centimetre, and a gas pressure of 200 lb per square inch; (*c*) a self-contained gas compression cable with a maximum stress of 150kV per centimetre and a gas pressure of 250 lb per square inch ; (*d*) a second low-pressure oil-filled design with a maximum electrical stress of 130kV per centimetre.

The cable lengths are of the order of 100 yards, and are all laid direct in the ground. Performance has been perfectly satisfactory throughout.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents.)

THERMAL INSULATION OF FACTORIES

SIR,—Your leading article " Thermal Insulation by Compulsion," was of particular interest to us as structural thermal insulation engineers. Not that this proposed Bill brought in by Mr. Nabarro is unknown to us, but rather your approach to a subject which is at once controversial and propitious. The severe fuel shortage and high costs at this time are very much to the fore in the minds of those concerned in the direction of industry, but it is remarkable that in view of the various schemes and incentives which have from time to time been offered by the Government to encourage fuel saving as a national economy, it has now become necessary to introduce a " Compulsory Bill."

Although thermal insulation has been applied in one form or another to industrial buildings for the past twenty-five years or so, it is only during these post-war years that its importance is becoming more generally accepted by those concerned. " Generally accepted " is stated in a very wide sense, but how slow this acceptance is ! Reduction of heat loss and the consequent saving in costs of fuel and plant for the heating of industrial buildings is the primary function of thermal insulation and by virtue of the fact that in most factory buildings a reduction in heat loss of 50 per cent or more can definitely be effected, it is a matter of some astonishment that every factory owner in the country does not investigate the merits of efficient thermal insulation and, equally important, the economics which attend this commonsense approach. We do not necessarily support legal compulsion ; actually we agree that there must be many instances where the thermal insulation of certain structures would not be advantageous, apart from an æsthetic gain, with which we are not concerned in principle. We do not, however, agree that there is any wide margin in the recommendations of insulating a new or an old building. The object is the same in both cases ; and more particularly we would emphasise that when you state that " it is one thing to incorporate insulation into a building during erection, it is quite another to require it to be applied to a building that is already in use, particularly should the alteration interfere with production," this is certainly not in the proportion you infer. In our own metal fixing system for the lining of factory roofs and walls the entire lining is carefully prefabricated in our works in accordance with final drawings and is in principle a matter of assembling only on site. Interference with production beyond the most minor extent is quite unnecessary, and those contemplating the lining of their premises, but with the worry of product loss, really can with confidence dispose of this anxiety.

In offering comment on your article our position may be somewhat invidious. We do, however, feel quite sincerely the need for a national effort to reserve fuel, and full confidence in the efficiency of quality thermal insulation leads us in the interests of industry to support the Government's action. The scheme could effect tremendous fuel saving and achieve a real service to industry. Finally, if we may, we would advise those who doubt the value of thermal insulation to refer to the National Industrial Fuel Efficiency Service, which has recently issued a very useful little booklet, *The Facts About the Thermal Insulation of Buildings*. This has quite an independent outlook in the interests of industry and confirms the real advantages of thermal insulation, together with the encouraging aspects of capital recovery. In assessing the real value and saving through thermal insulation it is, of course, necessary to review the needs of each and every factory on its individual merit.

GEORGE T. NOBLE

Director, W. H. Heywood and Co., Ltd.

Huddersfield, April 5, 1957.

DIESEL RAILWAY TRACTION

SIR,—The editorial article on the above subject printed in your impression of March 29 last, discussing the question of motive power for British Railways, is opportune because, as you rightly state, this continues to be a topic of much interest and not a little controversy In a communication such as the present, it is obviously impossible to deal with the question of steam versus diesel-powered locomotives as fully as it deserves ; nevertheless, it may be possible to offer a few remarks on what you describe as one of the special attractions of this form of motive power (meaning diesel power), namely, its high availability

You are undoubtedly right in mentioning this point, which is important for the reason that the availability factor is a measure of the number of power units it is necessary to provide to operate a given traffic It indicates the ratio of the locomotives in stock to the locomotives available for service, assuming, of course, single units which may or may not be the case with diesel-powered locomotives. So far as steam power is concerned, there is a certain amount of information available which seems to point to an average availability factor of 80 per cent. On the other hand, it is probable that little is positively known as to the availability which may be expected with main line diesel traction, though some deductions may be made.

Considering steam, probably a paper by S. B. Warder, Inst.Loco.E., 1951, and Colonel H. Rudgard's Presidential Address, Inst. Loco.E., 1948, may be recommended as giving the required information. The former contains particulars of engine working and indicated amongst other things an availability of 80 per cent for steam power. Colonel Rudgard, on the other hand, gives values which differ quite considerably and which, without further information, are not easy to understand. However, a detailed statement presented in graph form indicating the average disposition of the engines shows an availability of 80 per cent, meaning that 20 per cent are stopped either at terminals for one reason or another, or are in the hands of the C.M.E. shops. Under certain circumstances, steam power can and has improved on the percentage value mentioned. For instance, the working of some Beyer-Garratt articulated locomotives between Nairobi and Kampala, a run of 553 miles on the Kenya and Uganda section of the East African Railways, may be mentioned. During the years 1942 to 1945, the average mileage operated per available engine per month was 5420, 5174, 5366 and 5573, and of the twelve engines of a particular class assigned to this service the average numbers in actual traffic were 10·32, 10·97, 10·81 and 10·62, giving, therefore, availability factors of 86, 91, 90·5 and 88·4 per cent.

While much attention is given to the availability factor, it must be remembered that a high rate of potential availability is of no value unless it is utilised ; further, it is in utilisation that considerable improvements appear necessary. Colonel Rudgard made a great point of this and in doing so called for what he termed the " rescheduling of the schedule." If the mileages made by steam locomotives per day are considered in conjunction with the class of traffic worked and mean journey time speeds, it will quickly be realised that utilisation factors have little relation to the availability built into modern steam power and added to by expeditious handling at motive power depots and in the shops. This point may be illustrated by considering the working of some " Pacific " type engines used in express passenger services. The total annual mileage is 1,459,310 and the total engines in stock are twenty-nine, which, with an availability factor of 80, gives twenty-three as the number available. The annual mileage per engine in stock is, therefore, 50,321 and per engine actually available 63,448. Now, if it is assumed that mean journey time speeds are 45 m.p.h. and that the miles run per day per available locomotive are 174, being the annual mileage divided by 365, then the hours actually worked per day in revenue-earning service are 3·9, representing a utilisation factor of 16·2 per cent. These computations are admittedly not positive, but they are surely indicative.

Turning now to diesel power, as previously stated, little information is so far available, though various values have been quoted. It has been stated the B.R. 0–6–0 diesel shunters show availabilities of from 75 to 85 per cent. So far as main line diesel operation is concerned, Julian S. Tritton, Diesel Engineers and Users Association, 1956, presented some computations, officially sponsored, which indicated utilisation factors of 80 and 85 per cent for steam and diesel locomotives, based on the relative total numbers of power units required and those actually engaged operating defined diagrammed workings.

Based on facts and allowable deductions,

it would seem rather difficult to express hard and fast opinions on this very important matter. If, in fact, diesel locomotives can show a high rate of availability, it is certain that this advantage must be exploited to the full if they are to be economic. The total capital charges incurred in changing over to an entirely new form of locomotive for all classes of traffic will be very considerable and, as such, present a formidable obstacle to be overcome before financial justification can be realised.

E. C. POULTNEY

London, N.W.3,
April 6, 1957.

TERMINOLOGY IN GEARING

SIR,—In his letter under this heading, in your issue of March 29, Mr. Candee says, "The numbers of teeth and their size determine the diameters of the gears . . ." but this is hardly in accordance with usual practice. The diameters are broadly determined by centre distance and ratio. The size and shape of the teeth of a gear are determined by those of the teeth of the generating cutter, by the diameter of the blank (which may have any value within a definable range), and by the number of teeth generated in the blank.

One may agree with Mr. Candee in his remark that "From the beginning, the pitch circles in a pair of gears have been those touching each other and on both of which the circular pitch has the same value." As the sizes of these circles are clearly dependent on the centre distances of the gears, the term "pitch circle" can have no meaning when applied to any particular gear unless a mating gear and a meshing centre distance are specified; until a gear is meshed with another gear, it has no pitch circle. Mr. Candee writes: "Every gear . . . may have several (pitch circles)" and this fact deprives the unqualified term "pitch circle" of meaning. When an adequate qualification is added, the word "pitch" becomes superfluous.

No special virtues are claimed for the term "meshing circle" except that it does not use the word "pitch" and it refers to something essentially associated with the meshing of two gears. It admits of no qualification. If two gears are meshed together, the diameters of their meshing circles are precisely defined by the centre distance and the numbers of teeth. If a gear is not meshed with another, it has no meshing circle. Even if one likes to call the meshing circle the "pitch circle," the essential facts remain unaltered. In different circumstances any one gear may have different meshing circles, but the consequent uncertainty is of no practical importance as it is not necessary to consider meshing circles in design, manufacture, inspection or operation.

In British Standard practice the circle on which the pitch is that of the British Standard cutter that might have generated the teeth is called the "reference circle." It might have been called the "standard circle" but it is British Standard practice to restrict the word "standard" to subjects of standardisation by the Institution or by comparable institutions. But even if "standard circle" were permissible, there would be no object in expanding it to "standard pitch circle." Commonsense would suggest that "pitch circle" (like any other term) should be restricted to a single meaning, but as it has already gone far beyond that, the only safe measure for the future is not to use it at all.

W. A. TUPLIN

Sheffield,
April 1, 1957.

Literature

Freehand Drawing and Pictorial Illustration for Draughtsmen. By W. H. KERRY. The Association of Engineering and Shipbuilding Draughtsmen, Onslow Hall, Richmond, Surrey. Price 3s.

THIS, the second edition of a booklet first published in 1940, sets out to provide an elementary guide for the use of draughtsmen in making freehand drawings and pictorial illustrations. The author, in his introduction, acknowledges the difficulties which can accompany a mechanical draughtsman's attempts to produce freehand perspective drawings, and the fact that technical illustrations—as they are now well known in their established form—require an entirely different training and angle of approach has, of course, led to the compilation of the recent City and Guilds syllabus (No. 228). The booklet is in no sense intended to be used in connection with such examination courses.

Some of the illustrations used as examples in the text approach the standard required in the various fields of the modern technical illustrator's art, but in the majority of cases their principal application would lie in the direction of training the draughtsman to make sketches for internal works use, or in portraying "site" details from which mechanical design drawings can later be made. It is of importance to draughtsmen (and others) wishing to enter the field of technical illustration that they should note the standard of finish demanded by those responsible for producing publications—as well as accuracy in conception or appreciation of the subject matter and in the making of the perspective drawing itself.

There is much to be learnt about the presentation of this subject, and possibly the training of a draughtsman to undertake a form of illustration not normally coming within his purview needs especial care, lest his abilities in the one direction become lost to the community, whilst the work which he is attempting does not quite reach the level to which he should aspire. Technical illustration involves the mind, skill and outlook of an artist, allied to a liking for technical subjects—and an ability to read engineering drawings rather than to make them.

The Art and Science of Protective Relaying. By C. RUSSELL MASON. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 96s.

IT is not unusual for books to be created out of notes prepared for a continuing course of lectures. Provided that the notes are kept up to date, the resulting book stands a better chance of success than one "starting from scratch." The proviso has been honoured in this book, which is, in consequence, authoritative and comprehensive. Since the author's primary allegiance is to manufacturing, the work has a practical, rather than an academic, emphasis. Mathematics are used mainly to express the characteristics of relays, i.e. to relate torque or response to values of current and voltage and their phase angles, and to calculate those values for different system fault conditions. The latter exercise is not essential to an understanding of the principles of protection; but the former will be found very useful, even by those who do not fully understand the mathematics, in explaining, for example, how relays can be made to measure such quantities as impedance, reactance and admittance, and what an "off-set mho" relay is. In this explanation the *X–R* diagram plays a prominent part and its use also is explained.

The book opens with a chapter on the general "philosophy" of protection, in which, strangely, space is devoted to speculation about the relative roles of the operating staff and automatic protection (or relaying), as if they were in any sense alternatives. Other chapters deal very adequately with the application of relays to protective schemes for generators, transformers, busbars and lines, and very appropriately, since all the schemes employ them, there are chapters dealing with the characteristics and performance of current and voltage transformers. These are as prescribed by the American Bureau of Standards (A.S.A.). Although the author has long been associated with a particular firm's products, he has achieved a sufficient objectivity by concentrating on principles rather than the details of the different methods of applying them. The book therefore will not be quickly outdated, and even if new principles come to the fore, e.g. transistorised schemes, the existing schemes will remain for a long time in sufficient numbers to maintain its usefulness as a reference book and aid to teaching. This, admittedly, is true of North American relaying practice; but, by and large, it goes for British practice too. Differences there are, but they are fewer than might be expected, and these are mostly in matters of practice and not of principles. Each chapter is rounded off with an ample bibliography and, unusually, one or more examination questions (without answers).

Books Received

Ventilatoren. Third edition. By Bruno Eck. Springer-Verlag, Berlin W.35. Price DM.45.

Journal of the Institute of Metals, 1954–55. Institute of Metals, 4, Grosvenor Gardens, London, S.W.1. Price 60s.

Engineering Mathematics. By K. S. Miller. Constable and Co., Ltd., 10, Orange Street, London, W.C.2. Price 47s. 6d.

The j Operator for Electrical Engineers. By Philip Kemp. Macmillan and Co., Ltd., St. Martin's Street, London, W.C.2. Price 21s.

Hütte, IV A, Elektrotechnik. Twenty-eighth edition. Wilhelm Ernst and Sohn, Hohenzollerndamm 169, Berlin-Wilmersdorf. Price DM.49.

Metallurgical Abstracts, General and Non-Ferrous. Vol. 22. 1954–55. Institute of Metals, 4, Grosvenor Gardens, London, S.W.1. Price 60s.

Hygrometry. By H. Spencer-Gregory and E. Rourke. Crosby Lockwood and Son, Ltd., 26, Old Brompton Road, London, S.W.7. Price 36s.

1957 *Finishing Handbook and Directory.* Edited by I. S. Hallows. Sawell Publications, Ltd., 4, Ludgate Circus, London, E.C.4. Price 37s. 6d.

Physics. Second edition. By S. G. Starling and A. J. Woodall. Longmans Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 55s.

Principles of Forced Circulation in Hot Water Heating Systems. By Sigmund Pumps, Ltd., Team Valley Trading Estate, Gateshead, 11. Price 3s. 6d.

Stress Corrosion Cracking and Embrittlement. Edited by W. D. Robertson. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 60s.

Strength of Materials. Eighth edition. By F. V. Warnock. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 25s.

Third International Congress on High-Speed Photography. Edited by R. B. Collins. Butterworth's Scientific Publications, Ltd., 88, Kingsway, London, W.C.2. Price 70s.

Wärmediagramme für Vergasing, Verbrennung und Russbildung. By F. Bosnjakovic. Springer-Verlag, Berlin, W35, Reichpietschufer 20 (West Berlin), Ganzleinen. DM.43.50.

Electrical Engineers Exhibition

No. II—*(Concluded from page 535, April 5)*

The Electrical Engineers Exhibition at Earls Court was opened on April 9, by Sir Edward Boyle, Parliamentary Secretary to the Ministry of Education, and will remain open to the trade until to-morrow from 10 a.m. to 7 p.m. There is a large stand devoted to the theme of training and education in the industry and Government services in which a number of organisations are co-operating, including The Illuminating Engineering Society, The Central Electricity Authority, the G.P.O., the B.B.C., the Royal Navy, and the Royal Air Force. A total of 380 exhibitors are taking part in the exhibition this year. Some of the exhibits are described here.

Partridge Wilson and Co., Ltd.

A NEW design of transformer which has been developed for rural electrification schemes is being shown by Partridge Wilson and Co., Ltd., Evingdon Valley Road, Leicester. The example illustrated in Fig. 9 has a rating of 15kVA, single phase, and a ratio of 11kV/250V. It is oil-immersed, naturally-cooled, and is designed for a copper loss of 485W and an iron loss of 45W. The stepped core is wound from

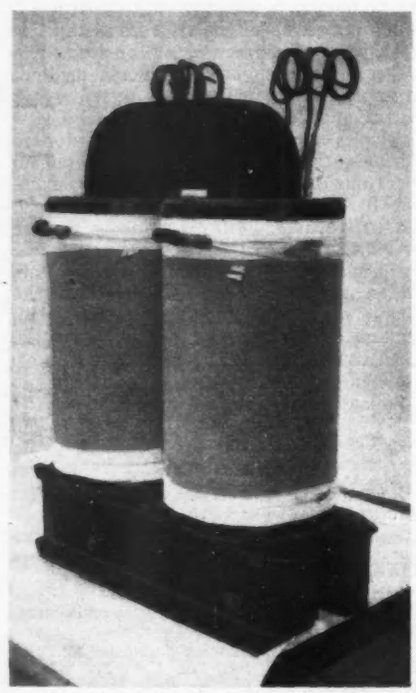


Fig. 9—Single-phase, 15kVA pole-mounting transformer with a continuous ring core of cold-rolled grain-oriented steel—Partridge Wilson

continuous strips of high-grade cold rolled, grain-oriented steel operating at a flux density of 15,000 lines per square centimetre. The coils are wound toroidally on the core. Compared with the traditional method (whereby the wound coils are slipped over the core limbs before completing the core by fitting the top yokes), the construction illustrated here, with its continuous ring core and smoother corners, offers the advantages of reduced iron loss and weight.

The same design principles are to be applied initially to a range of single-phase pole mounting transformers with outputs up to 50kVA.

Electric Construction Company, Ltd.

Medium and heavy electrical engineering equipment is being shown by the Electric Construction Company, Ltd., Wolverhampton. One of the main exhibit is a 920 h.p., 6·6/3·3kV dual-voltage, three-phase, 300 r.p.m. synchronous motor (0·9 p.f. leading), designed for auto-transformer starting and for air compressor drive for the South Western Division of the National Coal Board. The machine is shown in two sections for convenience of examination. The display also includes a multi-panel, heavy-duty contactor control switchboard arranged for controlling 50kVA standby power equipment in a telephone repeater station. The switchboard is arranged for the completely automatic control of an unattended station. Provision is made for remote control for testing out from a distance. The switchboard controls a " No-Break " diesel-electric generating set with a separate standby diesel-electric set. On mains failure the " No-Break " set takes up the load, and in the event of failure of the " No-Break " set the standby set comes into operation.

Two 1250A, 125V germanium rectifier units are on show, coupled together and complete with a power transformer feeding them.

Another exhibit is an electronically controlled speed regulator as provided for Ward-Leonard equipments of 150 h.p. up to 350 h.p. capacities. The regulator is designed to keep the output speed constant between the limits of ±1 per cent between no-load and full-load on the driving motor.

Newman Industries, Ltd.

An example of every frame size in the company's ½ h.p. to 600 h.p. range of drip-proof motors is shown by Newman Industries, Ltd., Yate, Bristol. Prominence is given to the recently introduced range of ½ h.p. to 50 h.p. drip-proof motors, which is characterised by the use of class-E insulation and complies with the new B.S. draft specification CW (ELE) 6246.

A new design of totally enclosed motor known as type " JC " is also on view. It is cooled by a double air circuit system which results in greater output from a frame size of given overall dimensions. It has two separate air circuits as can be seen from Fig. 10. The warmer internal air, which is circulated through the stator core by an internal fan, is channelled through ports in the end brackets, to the outer cooling surface of the frame. The cool external air is drawn by a second fan, through a second set of ports in the end brackets and directed over the stator frame. Heat transfer takes place between the two air circuits. Particular care has been taken to ensure total enclosure. For example, the bearings (roller at the drive end, ball at the non-drive end) are protected against the entry of dust by labyrinth seals, and the terminal box is of a dust-tight design. The fan guard is easily removed by undoing two bolts, giving direct access to the ports for cleaning. The electrical specification is to B.S. 2613 : 1955, Class A insulated, 55 deg. Cent. temperature rise. The octagonal cross section of the frame, facilitates the design of the air circuits and contributes to some saving of space.

Other new exhibits include one of the new drip-proof, vertical, hollow-shaft motors, together with a totally enclosed version. These motors are part of a range of four kinds of motors designed primarily for deep well pump applications (totally enclosed frames with solid or hollow shaft 1½ to 20 h.p., drip-proof frames with solid or hollow shaft, 10 to 125 h.p.). These motors are provided with large bearings and bearing housings to permit very heavy thrust loads at high speeds.

Square D, Ltd.

New control gear exhibited by Square D, Ltd., 100, Aldersgate Street, London, E.C.1, includes class " 8538 " combination starters and class "8630" star-delta starters. The combination starters, one of which is illustrated in Fig. 11, consists of a class " 8536 " line-voltage magnetic

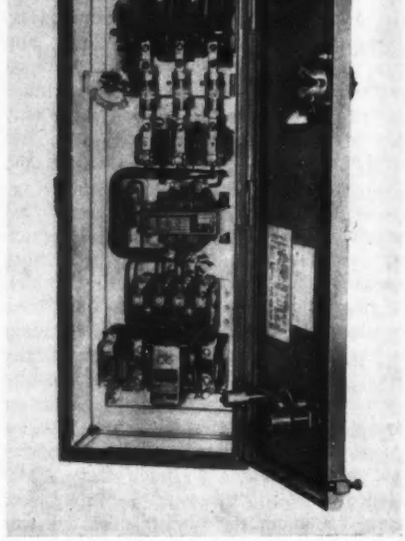


Fig. 11—A.C. combination starter consisting of magnetic starter with load breaking disconnect switch —Square D

starter, with a new interlocking load-breaking disconnect switch, fitted as a single unit in a dust-tight oil-resisting metal case. The disconnect switch which can be fused, if required, consists of quick-make-and-break blades with silver-plated contact faces operating in arc chutes with magnetic blow-out ; it is rated to interrupt repeatedly a stalled motor load. This switch is operated by means of a handle on the cover of the case and the handle can be locked open to prevent inadvertent switching on.

Overload protection on the starter is provided

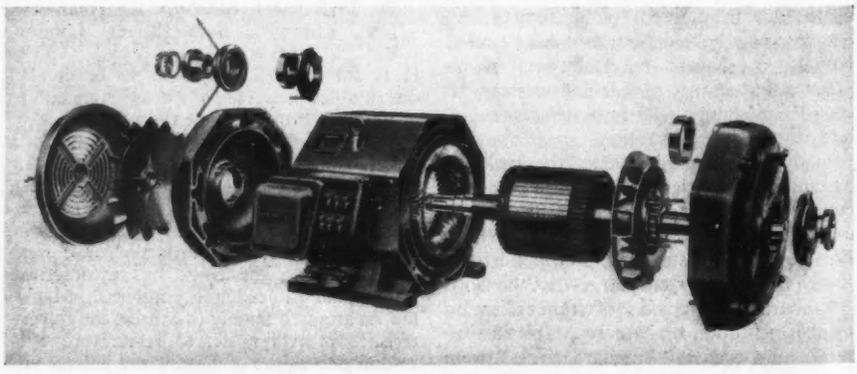


Fig. 10—Totally enclosed motor cooled by double air circuit—Newman

by melting alloy thermal overload relays with an inverse time characteristic which prevents them from tripping on normal starting surges or harmless momentary overloads. Fusible models are easily converted from British h.r.c. fuses to Canadian-American fuses. A low-voltage control circuit transformer is available as a standard accessory.

Another new product to be seen on this stand is the class "8702" reversing contactor, which consists of two magnetic contactors mechanically interlocked, and mounted on a common base. An electrical interlock prevents both coils from being energised at the same time and a mechanical interlock prevents the main contacts of one contactor from closing when the contacts of the other are closed. These reversing contactors are intended for starting, stopping and reversing a.c. squirrel-cage motors where other provision is made for overload protection or where overload protection is not required.

English Electric Company, Ltd.

A new range of metal-clad fuseboards is being shown by the English Electric Company, Ltd., Marconi House, Strand, London, W.C.2. This "Red Spot" distribution fuseboard is designed to give greater safety to operating staff. Accordingly, all "live" metal parts in the fuseboard are enclosed by insulation and each fuse contact is shielded by an insulating shroud so that when a fuse carrier is removed (Fig. 12) no live metal is exposed. All fuse carriers and bases are so designed that, no matter how the fuse carrier is held while it is being withdrawn or inserted, "live" metal cannot be touched. Each incoming cable socket is covered by an insulating housing designed to fit snugly over the insulation on the incoming cable. Each fuse fitting has an insulating sleeve, to give adequate protection should the insulation on the outgoing cable be stripped back too far. The fuseboard is fitted with a built-in cylinder lock to prevent unauthorised access.

When connecting-up outgoing circuits the insulating shroud encasing each fuse terminal can be removed without disturbing the shroud enclosing the busbar contact. This facility is useful in instances where spare circuits must be connected while the busbars are "alive." The fuseboards incorporate the company's "T"-type non-deteriorating cartridge fuse links, all sizes of which have received A.S.T.A. certificates of rating for category of duty 440AC5 to B.S. 88 : 1952, that is for 35MVA at 440V, three phase.

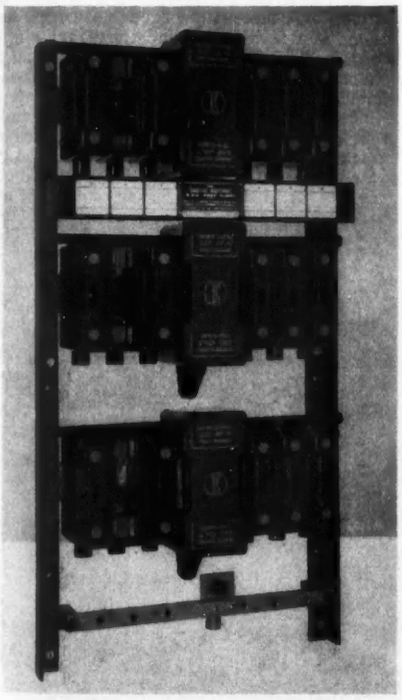


Fig. 12—Interior front view of "Red Spot" fuseboard removed from its metal case to show insulation enclosing all live metal. The fuse carriers are removed from No. 2 circuit to show the insulating shrouds covering the fuse contacts—English Electric

Crompton Parkinson, Ltd.

Recent developments in industrial motors are to be seen on the stand of Crompton Parkinson, Ltd., Aldwych, London, W.C.2. Some of the new Series-5 machines, for example, are on show. They typify a new range of ventilated a.c. three-phase squirrel-cage motors (with outputs from 1 to 50 h.p.), recently introduced by the company to take advantage of the draft specification CW (ELE) 6246, which provides for the use of class E insulation and allows for motor operation at continuous maximum ratings with a temperature rise of 65 deg. Cent. With this provision and with an improved cooling system the size and weight of motor for a given horsepower rating have been reduced by as much as 40 per cent.

A four-pole foot-mounted motor of 0·95 h.p. is representative of the recently developed totally enclosed fan-cooled ratings which have been

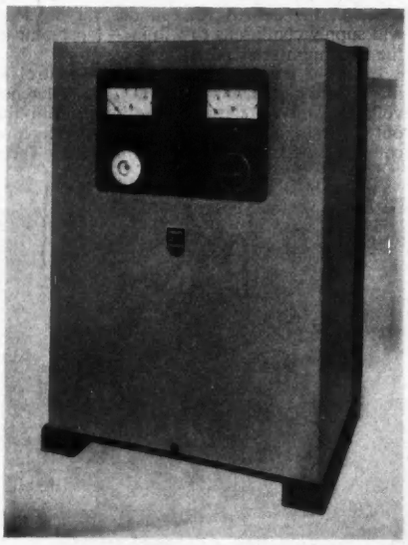


Fig. 13—Voltage stabiliser with output of 1·5kVA/2kVA. The output voltage is controlled by a transductor in series with part of the main transformer winding—Philips

added to the company's "general-purpose" three-phase range of fractional horsepower motors.

Amongst the instruments on show is a new three-phase tachometer generator which consists of a miniature three-phase alternator and a rectifier type of moving coil voltmeter. At slow speeds this instrument gives a steadier reading than that obtained from a single-phase tachometer generator.

Philips Electrical, Ltd.

A recently introduced range of a.c. voltage stabilisers with outputs from 300VA to 6kVA are being exhibited by Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2. They are designed for use with any laboratory or industrial equipment which requires a constant input voltage.

In the 300VA equipment stabilisation is effected by two transformers connected in series, the first having an unsaturated and the second a saturated core. A capacitor is fitted to compensate for load variations. Stabilisers are available for 50 c/s or 60 c/s working at 220V nominal input. The output is within ±1 per cent of 220V for mains fluctuations from −15 to +10 per cent. This equipment weighs only 39 lb, measures 14½in by 8in by 7in, and is available in chassis or cased form for either vertical or horizontal mounting.

Output voltages of the 1kVA, 1·5kVA, 2kVA and 5kVA equipment are controlled by a transductor in series with part of the main transformer winding, any slight variation in secondary voltage being eliminated by a bridge circuit and amplifier. A safety relay automatically reduces the secondary voltage if this voltage rises above a certain level. These stabilisers are designed to be independent of frequency variation, and of relatively large fluctuations of power factor; filters ensure a good sinusoidal shape to the secondary output. These larger stabilisers are available for either 110V, 127V or 220V nominal input at 50 c/s (also 60 c/s in the case of the 5kVA model). Variations in the mains voltage from −15 to +10 per cent and of ±3 per cent in frequency are permissible for an output within ±0·2 per cent of the nominal voltage. For the 1·5kVA model, mains voltage fluctuations can be from −30 to +10 per cent.

All stabilisers are fully "tropicalised" and the larger equipments (Fig. 13) are housed in lacquered steel cases on the front of which are mounted a mains switch, input and control circuit fuses, voltmeter, ammeter, pilot lamp and an adjustment for setting the output voltage.

Heenan and Froude, Ltd.

A "Heenatone" programme controller unit, designed for supervising a repeated cycle of operations, is being shown by Heenan and Froude, Ltd., Worcester.

The equipment consists of an electronic frequency generator unit which is used to produce tones of various frequencies. These tones are selected by push buttons, the number used depending on the number of separate operations required in the sequence. The tones are recorded on a magnetic tape and the recorder is connected to an electronic frequency selecter which identifies the various tones and operates the appropriate contactor to initiate the final motion or operation. With this system a library of recorded schedules can be stored for long periods, if necessary. Alternatively, out-of-date operations can be erased and a new set recorded on the same tape. This equipment is shown controlling a variable-speed drive in accordance with a predetermined sequence.

Smiths Industrial Instruments, Ltd.

A new relay calibrated to ±1 per cent for the control of voltage current or speed is exhibited by Smiths Industrial Instruments, Ltd., Chromos Works, North Circular Road, London, N.W.12. This relay embodies a new approach to the problem of closing a pair of contacts precisely at a predetermined electrical input. It consists of a permanent magnet and coil system similar to that used in a permanent

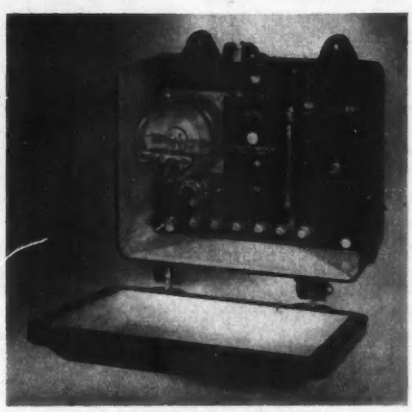


Fig. 14—An overspeed control unit with the sealed calibrated relay on the left, a three-circuit latched relay in the centre, and a test circuit button on the right to facilitate operational checks without disturbing the input quantity—Smiths

magnet loudspeaker, which gives a very high efficiency of conversion from electrical energy to mechanical force.

Contact closing is effected by a special magnetic lock, which can be adjusted accurately to a pre-selected value. This lock opposes the motion of the moving coil until the force developed by the moving coil exceeds the magnetic locking

force, when the contacts close with precision under static conditions of ±1 per cent of the setting value with a snap action, resulting in an immediate rise of contact pressure in excess of 20 grammes. It is designed to operate on low power inputs. The relay consumes between 20mW and 30mW. The contacts are normally approximately ⅛in apart and the relay setting is not affected by contact wear.

The actual setting can be controlled externally by the use of a series or shunt trimmer, or a directly calibrated resistance can be provided to vary the setting according to requirements. The resistance of the moving coil is low enough for operation directly from instrument rectifiers and therefore both a.c. and d.c. quantities can be controlled.

The relay is fitted on many of the new British Railways diesel railcars to give starter protection and automatic control of starter operation in each coach without the necessity for additional intercoach wiring. It is also being fitted as a diesel engine overspeed control device on some of the British Railways main line locomotives.

In Fig. 13 we show an overspeed control unit with the sealed calibrated relay on the left, a three-circuit latched relay in the centre, and a test circuit button on the right, to facilitate operational checking without disturbing the input quantity.

Standard Telephones and Cables, Ltd.

The manufacture of power transformers is a new departure for Standard Telephones and Cables, Ltd., Connaught House, Aldwych, London, W.C.2. For, although the company has been making transformers for about fifty years, these products hitherto have been used exclusively in the S.T.C. telecommunications and rectifier equipments. Now, however, this experience is to be applied to the production of standard ranges of power transformers for the open market. At present, the range extends up to 50kVA and it is being expanded up to outputs of 1MVA. The existing range of single-phase and three-phase transformers includes open, "potted," C-core and hermetically sealed equipments, a representative selection of which is being exhibited.

The possibilities of high-temperature operation, and the high electrical efficiency of "SenTerCet" silicon rectifier transformer equipments are demonstrated by a working exhibit. The equipment on show will be operating with a 415V, 50 c/s, three-phase input and will give an output of 400V at 15A. Part of the d.c. output load is in the form of electric heaters to provide a 70 deg. Cent. ambient temperature to the equipment. For exhibition, the equipment cubicle is fitted with an inspection window for viewing the interior electrical equipment and an internal thermometer. Meters are provided for input and output circuits to permit efficiency calculations to be made at varying loads.

New thermionic valves are also being exhibited. They include two new hot-cathode zenon-filled rectifiers—"SV-3B28" ("CV1835") and "SV-4B32" ("CV2518")—which are designed to operate at 10kV maximum peak inverse voltage and average anode currents of 0·25A and 1·25A respectively. Two new forced-air-cooled triodes ("3J/202E" and "3J/222E"), specially designed for use in r.f. heating equipments, are also on show. They are designed for long life expectancy, giving nominal outputs of 10kW ("3J/202E") and 20kW ("3J/222E") at an anode voltage of 6000V. Water-cooled versions of these valves are also made.

Laurence, Scott and Electromotors

The N-S variable-speed a.c. motor developed by Laurence, Scott and Electromotors, Ltd., Norwich, is demonstrated with "Asrec" automatic control and with "Velonic" control of speed.

It may be recalled that the N-S motor is a stator-fed variable-speed a.c. machine in which an induction regulator is used to control the speed over a wide range under all loading conditions, without brush movement. This induction regulator can be operated by hand, by remote push button or by various kinds of automatic devices. In the demonstration of "Asrec" speed control the equipment consists of a standardised system which makes use of a sensitive polarised relay and stabilising circuits for the signal voltage and a d.c. tachometer generator and potentiometer for the reference voltage. This system is designed to keep the speed at the desired value under varying load and supply conditions to within ±1 per cent of the maximum speed.

In the "Velonic" system speed control is maintained by comparing a d.c. reference voltage from an electronic stabiliser, with the output from a tachometer generator which is coupled mechanically to the motor shaft. Three decade resistance settings form part of the tachometer generator summing network and they are so arranged that the ratio of the summing network is changed when the preselected speed setting is changed. The error signal from the summing network (which gives a measure of the difference between the actual and desired speeds) is applied through a d.c. amplifier to two opposed field windings of a d.c. servo motor. This servo motor operates the induction regulator of the N-S motor until the required speed is attained. A second tachometer generator, coupled to the servo motor, provides a velocity feedback voltage to stabilise the system and prevent hunting. A compensating network is included to allow for the small speed changes caused by temperature and brush drop variations in the tachometer generator. It is stated that "Velonic" equipment will control motor speed to within about ±2 r.p.m. over the whole speed range (400 to 2000 r.p.m. in the case of the exhibit) despite supply variations of ±10 per cent in voltage and/or frequency. The long-term variation is stated to be within 0·2 per cent of the speed.

Another demonstration will involve a 7½kVA self-excited alternator with "Altoreg" control, the alternator being driven by the N-S motor of the previous exhibit and loaded by a 5 h.p., 1000 r.p.m. "Trislot" induction motor fitted with a mechanical brake. The "Altoreg"-controlled alternator has two separate field windings, the main one being excited by the load current through a current-transformer/rectifier system. In its simplest form self excitation is supplied by the second winding from a rectifier connected across the output terminals. With self-excited machines a regulation of about ±5 per cent can be attained over the rated load range with a high speed of response. The "Trislot" motor used in this demonstration is designed to take a starting current of about 3½ times full-load current and to develop 1½ times full-load torque.

In Fig. 14 we illustrate a totally enclosed high-tension air-cooled single induction regulator for use with an N-S variable-speed a.c. motor. It is offered as an alternative to the more familiar oil-immersed regulator. A small water cooler (not shown in the equipment illustrated in Fig. 14) is mounted behind the ventilating motor which stands on top of the frame of the equipment actually exhibited.

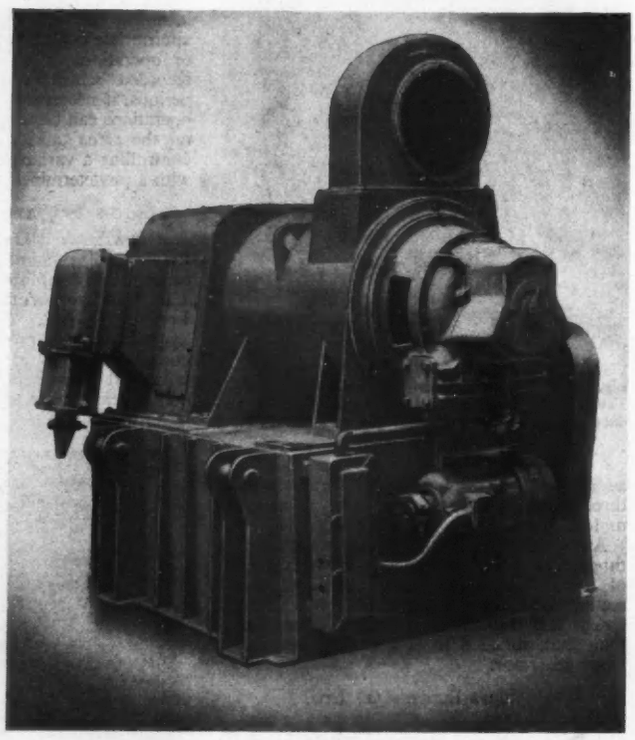


Fig. 14—Air-cooled induction regulator designed to take the place of an oil-immersed equipment. The air-water heat exchanger is omitted from this view—Laurence, Scott

Ferranti, Ltd.

A phase-earth loop impedance tester is one of the instruments shown by Ferranti, Ltd., Hollinwood, Lancs. This instrument, which is produced under licence from its British patentee, is intended for testing to Regulation 406 of the I.E.E. Regulations for the Electrical Equipment of Buildings. Instead of working on the current injection principle recommended in Regulation 507, the tester momentarily puts an actual fault from line to earth and is operated by the fault current. The fault current passes through a push button making switch, two miniature circuit breakers and a selected shunt. The circuit breakers interrupt the current in 1½ cycles. If the loop impedance is low enough to permit the passage of a fault current greater than the fuse rating marked on the shunt selector switch, a cold-cathode valve is triggered and glows continuously until reset. Thus a positive indication of the safety of the circuit is given as the result of an actual test. A voltmeter is incorporated in the tester and can be used to check the polarity of the supply. An additional scale is marked on the voltmeter to check the leakage current of an installation as required by Clause 26 of the Electricity Supply Regulations (1937). The

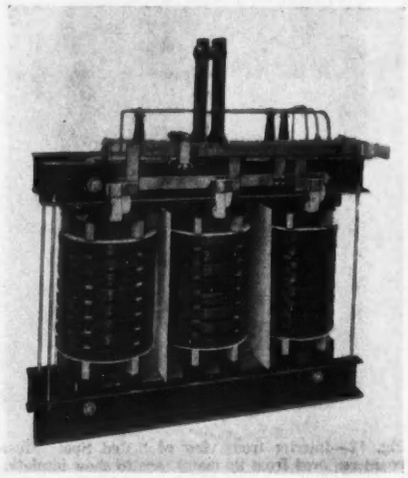


Fig. 15—500kVA, three-phase, 11kV distribution transformer with class-H insulation—Ferranti

tester complete with connecting leads 6ft long is fitted in an oak case with lid and carrying handle.

Among the products of the company's transformer department is a rural distribution transformer incorporating a new core design. The "Lock Wound Core" as it is called, consists of strips of low-loss grain-oriented steel wound into a coil, the overlapping joints being locked in position. As the flux path follows the grain of the steel and air gaps in the core are almost eliminated this design gives reduced magnetising currents and iron losses.

The display also includes a transformer with class-H insulation, showing the construction of the core and windings (Fig. 15). This class of transformer is characterised by the ability to operate at high temperatures without fire or explosion risk. The insulation has a smooth water repellent surface, which inhibits the collection of dirt.

Continuous Gauging of Hot-Rolled Steel Strip

A gamma ray thickness gauge has been developed by the Baldwin Instrument Company, Ltd., for measuring the thickness of hot-rolled steel strip as it passes from the rolls. Variations in strip thickness are shown by rows of lamps lighting up on a display board and recorded on a teleprinter.

IN the rolling of hot steel strip, where frequent resettings are called for to produce different gauges and widths, an appreciable amount of time can be lost after the initial adjustment of the rolls, in shearing off and gauging test pieces and making final adjustments to get the product within the desired tolerances. In order to overcome this loss of time and provide a continuous check on output size, a gamma ray transmission thickness gauge has been developed by the Baldwin Instrument Company, Ltd., Brooklands Works, Dartford, Kent, and a prototype production equipment installed on a strip mill at the works of Steel, Peech and Tozer, Rotherham. The regular use of this new gauging equipment enables the need for manual gauging to be reduced to a minimum, assists considerably in mill setting, and enables the actual thickness of the strip to be known at all points along a length instead of, as in manual gauging, at one point near the end. A tolerance limit can be set on the instrument to suit the rolling specification, which is usually in the region of 0·002in to 0·010in.

In this design of gauging equipment, measurement of the hot fast-moving strip coming from the mill is effected by non-contact means. It utilises a radioactive source on one side of the strip with a radiation detector situated at the other side of the strip. The intensity of the radiation falling on the detector varies with the thickness of the strip and causes the detector output to vary. The detector is coupled to an electronic equipment, through which its variations in output are displayed by means of a series of lamps which light on a display board in the mill and are recorded by a teleprinter.

The prototype installation can be seen in the illustrations on this page; it is fitted on a Morgan strip mill rolling strip up to 9in wide. It is arranged to measure thicknesses between 0·03in and 0·250in, the total span being divided into six ranges. The gauging head of the equipment can be seen in Fig. 2. The hot strip passes in a vertical plane at high speed between the radioactive source unit on one side of the head and the detector unit on the other side. The source assembly incorporates a special means of testing and adjusting the installation, which is brought into effect between strip runs when the instrument switches itself to a "standardise" condition. When this takes place a signal from the electronic unit causes a pneumatic cylinder to place a circular disc of metal of standard thickness over the radioactive source. The instrument then measures this standard and, if necessary, adjusts itself to give correct reading. Six standard metal discs are fitted in the source unit and the appropriate one is preselected by means of a switch on the operator's control desk.

The radiation sensitive element in the detector is a thallium-activated sodium-iodide crystal, which scintillates when radiation falls upon it. The visible light from the crystal is picked up by two photo-multipliers, one of which acts as the measuring device for the instrument, the other as a relay, which causes the changeover from the measuring to the "standardise" condition and vice versa. The output from the measuring photo-multiplier feeds into an integrating circuit, which averages the current over the time cycle of one second. The output from the integrator is then fed to the amplifier in an electronic unit.

Fig. 1—Hot strip mill, showing strip passing the measuring point where the source and detector units are situated beneath a protective cover

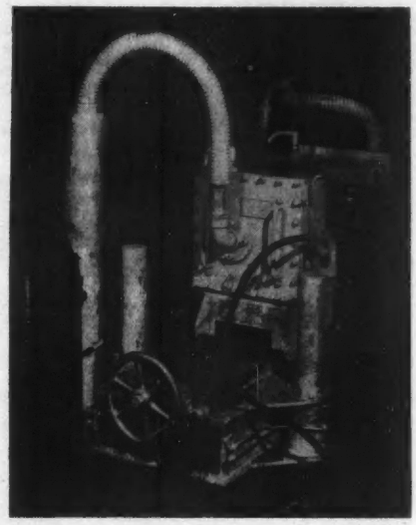


Fig. 2—Strip mill runout table with gauging head protective cover removed. The source holder is in the foreground and detector unit in the rear

When the trailing edge of a rolled strip passes through the measuring head there is a considerable increase in radiation reaching the crystal and a corresponding increase in visible light. The second photo-multiplier measures this change and causes the instrument to switch to the "standardise" condition, whereupon one of the six standard discs in the source unit is moved into position, thus reducing the radiation reaching the crystal. When the leading edge of the next strip from the mill arrives in the measuring head the relay photo-multiplier reacts to the sudden drop in radiation at the detector and restores the instrument to the measuring condition.

The source and detector units can be separated for maintenance and the removal of the water-cooled strip guide by turning a handwheel; the head can also be moved in a vertical direction by adjustment of a control wheel on the operator's console. This vertical adjustment allows the radioactive beam to pass through various points across the width of the strip and also accommodates variations of strip width. This head movement is carried out by a mechanism actuated by a power cylinder with accurate position control.

The electronic cabinet is situated in a separate room and houses the equipment for amplifying the signals received from the measuring head detector. The output from the amplifier is fed to a discriminator which classifies each signal into one of five levels, depending upon the magnitude of the signal, which, in turn, depends upon the average thickness of strip passing through the measuring head during the appropriate second. The five levels are arranged to represent: out of tolerance positive, intermediate positive, nominal thickness, intermediate negative, and out of tolerance negative. These five levels are represented by five banks of a uniselector which steps round at one second intervals over fifty contacts. Once every second an impulse is applied to one of the five uniselector banks, depending on the voltage of the signal entering the discriminator. The impulse is fed to one of the uniselector contacts and the appropriate relay is operated. It will be appreciated that each uniselector bank represents one of the five conditions of thickness.

The display board, which can easily be seen from all parts of the mill, consists of five horizontal rows of fifty lamps. The centre row of green lamps represents nominal thickness; the two rows of amber lamps, one on each side of the centre, represent the positive and negative

intermediate tolerances, and the two outer rows of red lamps indicate out-of-tolerance oversize and undersize conditions. In the vertical plane each bank of five lamps represents the mean thickness of the length of strip passing through the head in one second.

The lamps are operated by the relays connected to the contacts of the uniselector. Thus, for each second during which strip is passing through the measuring head, an impulse from the detector causes one of the five lamps in a bank to light, depending on the deviation of the strip from the preset thickness. As each strip moves past the gauge, the lamps which are illuminated trace out its thickness profile on the display board.

The display of lighted lamps is cancelled the moment the leading edge of the next strip arrives, and to provide a more permanent record of each strip a teleprinter is included in the equipment. On this teleprinter one of five keys is used to represent one of the five rows of lamps, so that a record sheet in the teleprinter shows symbolically that which is shown graphically for each strip on the display board.

Fig. 3—Part of the operator's control desk, showing alloy selector, set thickness control and tolerance control

The control desk, part of which can be seen in Fig. 3, contains all the controls which are necessary for the day-to-day operation of the equipment. It includes a thickness control, on which the required nominal thickness is set on a dial—the display board then shows deviations from this setting. A range selector on the desk preselects the standard metal disc for use in the standardising condition, and an alloy selector switch is set to the particular alloy of the strip being measured. A tolerance control on the desk enables the maximum and minimum tolerance limits for the strip to be adjusted.

The installation, apart from the usual test meters and switches, has been provided with means to test various portions of the equipment without the use of other main units. For example, if a fault is suspected in the control desk a simple adjustment at the rear of the instrument enables the desk to be disconnected entirely and replaced by a built-in test unit. To facilitate maintenance certain components, such as uniselectors and relays, are plug-in replaceable units.

1500 h.p. Main Line Diesel-Electric Locomotive for Malayan Railway

DIESEL-ELECTRIC traction is being introduced on the Malayan Railway line from Singapore to Prai via Kuala Lumpur, a distance of 488 miles, and the English Electric Company, Ltd., is supplying twenty 1500 h.p. locomotives for operation on this line and other parts of the system. Ten of these locomotives are being built at the company's Preston works and ten will be built by the associated Vulcan Foundry, Ltd. The first locomotive to be built on this order was completed recently at the Preston works, where it was handed over (on schedule) on March 29 by Mr. H. G. Nelson to Mr. C. G. Harrison, the general manager of the Malayan Railway.

These locomotives are designed to haul 450-ton passenger trains from Singapore to Prai in under fifteen hours with existing speed restrictions (55 m.p.h. maximum) and without assistance on the Taiping Pass section, which is characterised by severe curves and gradients of 1 in 80. With these locomotives, as was pointed out by Mr. C. G. Harrison at the handing over ceremony, it is hoped to save one hour in the scheduled run between Singapore and Kuala Lumpur.

The main particulars of the locomotives are tabulated here. The locomotive superstructure is carried on two three-axle bogies. Each axle carries a nose-suspended traction motor driving the road wheels through single reduction spur gearing. The floor plate of the underframe is unbroken throughout its length to eliminate the possibility of dirt from the track entering into the equipment compartments.

Particular attention has been paid to the design of the cast steel bogies to ensure good riding and to restrict throw-over on sharp curves. The cast steel bogies are of the swing bolster arrangement with under-slung compensating beams. Laminated springs are used between bolster arms and spring plank, while helical springs are interposed between the bogie frame and the compensating beams.

Main Particulars of 1500 *b.h.p.* C_0-C_0 *Diesel-Electric Locomotive*

Locomotive weight in working order	96 tons
Adhesive weight	96 tons
Maximum axle load	16 tons
Track gauge	Metre
Length over buffer beams	52ft 10in
Width over body	8ft 10in
Overall height	11ft 7¼in
Bogie wheelbase	12ft 9in
Bogie centres	27ft 9in
Wheel arrangement	C_0–C_0
Wheel diameter	38in
Brakes (locomotive and train)	Vacuum
Diesel engine	12 cylinders—supercharged
Rating	1500 h.p. at 850 r.p.m.
Number of traction motors	6
Maximum tractive effort	54,000 lb
Continuous rating	31,050 lb at 13 m.p.h.
Maximum service speed	60 m.p.h.
Fuel tank capacity	750 gallons
Air compressor	One, motor driven
Exhausters	Two, motor driven
Traction motor blowers	Two, motor driven
Radiator fan	One, mechanically driven

The two driving cabs extend over the full width of the locomotive, with the driving position arranged at one side of each cab, permitting the locomotive to be driven in either direction. Streamlined nose compartments in front of the driving cabs contain the traction motor blowers and exhausters.

The diesel engine is an English Electric "12 SVT" engine developing 1500 h.p. at 850 r.p.m. It is directly coupled to the 1000kW main generator and is supported on flexible bearers to relieve the engine bedplate of stresses which might otherwise develop as a result of normal flexing of the locomotive underframe in service. The engine has twelve cylinders (arranged in two banks at an included angle of 45 deg.), having a bore of 10in and stroke of 12in, and is pressure-charged by two Napier exhaust turbo-chargers mounted on the engine above the main generator. The engine is of monobloc construction with separate cylinder heads bolted to the crankcase casting and renewable wet cylinder liners. It operates on the four-stroke cycle with solid fuel injection. The crankcase is cast in two halves, which are bolted together to form a single unit which need not be separated during the lifetime of the engine. It embodies the cylinder jackets and camshaft casings and incorporates transverse diaphragms between cylinder bores. Besides forming the water compartments around the cylinder liners, the diaphragms stiffen the crankcase structure and support a series of bearings for the camshaft journals. Detachable doors are provided on both sides of the crankcase to facilitate access to the lower internal engine components such as main bearings and big-ends, and additional ports and inspection panels are provided for access to the camshaft drives, fuel pump tappets and the cooling water system.

Cooling water is circulated through the engine and radiators by two engine-driven centrifugal pumps. The provision of individual pipes to each cylinder head and the design of the water system prevent steam pockets in the cylinder jacket, and provide for temperature control over long periods of full power output. Automatic by-passes are provided to ensure rapid warming of the water to suitable operating temperatures. Automatic pressure lubrication is provided by an engine-driven gear pump which delivers oil from the main supply, through a filter and strainer, to the main supply rail in the bedplate; a relief valve, fitted on the inlet side of the filter, controls the pressure of the system. Circulated oil is drawn from the sump by a scavenge pump and passed through a radiator from which it returns to the suction side of the pressure pump. The main, big-end and camshaft bearings, small ends and governor, and the chain and auxiliary drives are supplied from the high-pressure system. A low-pressure oil supply is obtained, by means of a reducing valve, from the high-pressure system and is used for lubricating the valve gear. Valve and fuel pump cams revolve in oil baths and the pistons are lubricated by oil mist.

The control equipment is housed in a cubicle which is placed longitudinally in the engine compartment. This allows easy access to all parts of the cubicle and facilitates maintenance.

A compressor is provided for various locomotive services, whilst two exhausters are fitted for operating the vacuum brakes of the locomotive and train. Fuel is carried in a tank which is underslung from the locomotive underframe between the two bogies; the battery is mounted on either side of the fuel tank so that it is readily accessible for maintenance.

When required, two locomotives may be coupled together and operated in multiple unit.

Electrical Equipment

The main generator is a self-ventilated, separately excited machine with an additional series field used only when motoring the generator to start the engine. It is a flange-mounted machine with a single bearing, the flywheel end main bearing of the engine being increased in size as it has to bear part of the generator weight. The main generator supplies current to six axle-hung nose-suspended traction motors which are permanently connected in three parallel groups of two in series.

An auxiliary generator is overhung from the main generator and, in addition to providing excitation current for the latter, supplies the motor-driven auxiliary machines, battery charging, control and lighting. The motor-driven auxiliary machines include the traction motor blowers already mentioned, two Northey "90RE" exhausters, and a Westinghouse

"E25A" compressor. This latter supplies air for the horns, sanders and control gear.

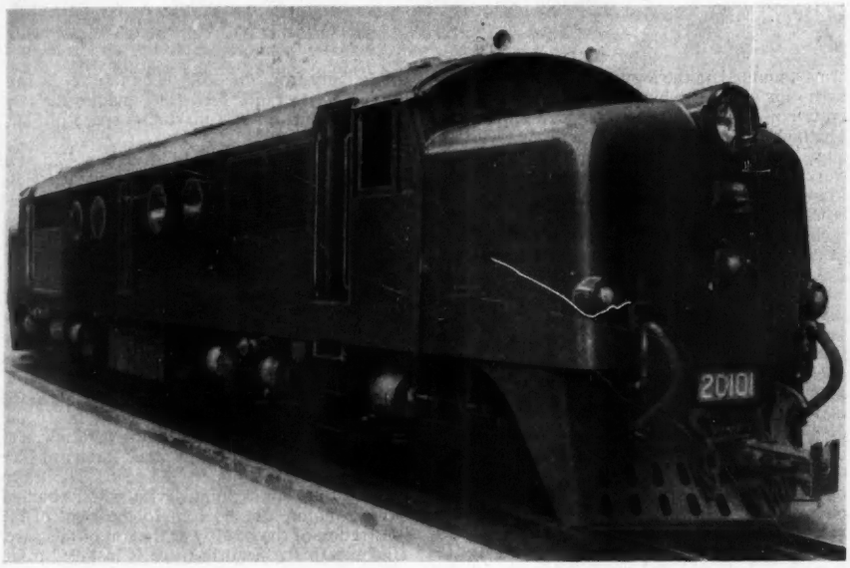
The radiator fan is mechanically driven from the free end of the engine. This fan, in addition to drawing air through the radiator panels, induces a considerable flow of air through the engine, thus maintaining it at a reasonable temperature.

The six traction motors are six-pole series wound d.c. machines with interpoles. Each motor is forced ventilated and has a one-hour rating of 195 h.p.; a motor blower set is mounted in each nose end compartment.

For speed control there are three stages of field weakening with diverter resistances. The method of control permits continuous variation of diesel engine speed and ensures that the full power available at any such speed can be exerted over a range of road speeds, effectively limited only by adhesion at the lower end and the maximum safe speed of the locomotive or traction motor at the upper. The main power controller has two handles; one is used for setting the reverser for the required direction of travel and the other controls the power developed by the diesel engine. Once the diesel engine has been started by motoring the main generator from the battery, the driver first sets the reverse handle and thereafter control is effected by the one handle only. On being moved from the "off" position, the control handle first causes the generator field and main power circuits to be completed and then steadily increases the diesel engine speed via an air-operated servo-mechanism. Movement of the handle operates a valve regulating the air pressure applied to a spring-loaded piston on the engine governor, so varying the diesel engine speed. Adjustment of the generator field and field weakening of the traction motors to suit the load conditions are carried out automatically by a motor-driven regulator controlled by load sensitive contacts on the engine governor.

With this system, the engine runs at the minimum speed necessary to produce the power demanded. This characteristic, besides reducing fuel consumption, results in less wear and tear on the engine.

Vacuum brakes are fitted on both the locomotive and train. The locomotive is equipped with the Gresham and Craven two-pipe system and has individual brake cylinders for each wheel.



The first of the twenty 1500 h.p. C_0-C_0 diesel-electric locomotives being supplied by the English Electric Company, Ltd., for main line service on the Malayan Railway. The six motors give a maximum tractive effort of 54,000 lb with a continuous rating of 31,050 lb at 13 m.p.h.

HEAVY CHROMIUM DEPOSITION PLANT.—A new plant for the electro-chemical deposition of chromium, which has been installed at the Port Glasgow works of Fescol, Ltd., is designed to accommodate components up to 15ft long, 5ft diameter, and weighing up to 6 tons.

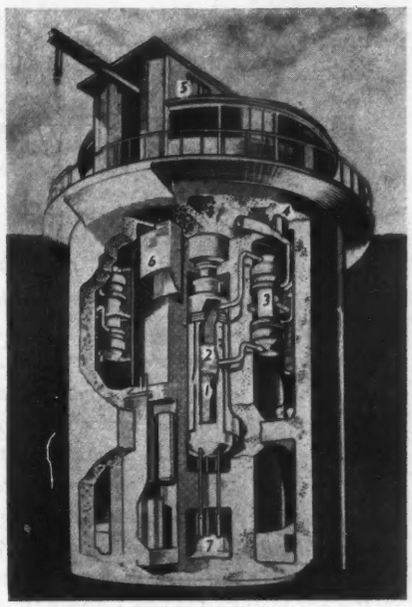
15MW Nuclear Power Station for West Germany

THE first nuclear power station in West Germany is to be built by Mitchell Engineering, Ltd., 1, Bedford Square, London, W.C.1, and A.M.F. Atomics, Inc., New York, on behalf of Rheinisch-Westfalisches Elektrizitatswerk A.G. The power station will incorporate a closed-circuit boiling-water reactor, a diagrammatic representation of which is reproduced here. It will be designed for an electrical output of 15MW and it is due to be in operation in the autumn of 1959.

It is estimated that the value of the nuclear work involved will be 5,300,000 dollars, about three-fifths of which will be received by Mitchell Engineering, Ltd. The reactor core and control system will be supplied by A.M.F. Atomics, Ltd., and the first loading of the core will cost about 1,500,000 dollars. Among the major participants in the contract will be Siemens-Schuckertwerke of Erlangen, who will supply the generating plant and switchgear. The site of the power station has not yet been decided but, as will be seen from the accompanying sketch, the reactor itself will be mainly underground. All the civil engineering work will be done by local labour and some of the materials required for the station will come from Germany.

In the closed-circuit boiling-water reactor plant, ordinary water, which serves as the moderator, is allowed to boil in the coolant passages in the fuel elements which are of uranium and thorium oxide clad in zirconium alloy. The assembly of each fuel element will be entirely mechanical and will not require metallurgical roll bonding or any precision machining. The fuel assemblies will make up a core 5ft in diameter and 5ft high. The use of oxide fuel avoids the possibility of chemical reaction of metal and water which might lead to a damaging explosion. The heat output of the reactor will be 58MW and the surface temperature of the elements will not exceed 550 deg. Fah. The pressure in the reactor vessel will be constant at 900 lb per square inch gauge, and the steam temperature will be 533 deg. Fah. The steam conditions before the main inlet valve of the turbo-alternator will be 600 lb per square inch and the temperature will be 489 deg. Fah. saturated; there will be no superheater. Provision has been made in the design of the reactor and core to allow complete flexibility in arrangements concerning the size and type of fuel to be used. The design is for natural circulation initially but forced circulation can be installed.

The core is surrounded by heavy steel plate and 9in of water serve as a reflector. The biological shielding will consist of the equivalent of a 4in steel plate and 7ft thick concrete with a minimum density of 125 lb per cubic foot.



1.—Reactor core.
2.—Boiling water.
3.—Heat exchanger.
4.—Steam outlet.
5.—Fuel handling room.
6.—Fuel storage tank.
7.—Control mechanism bay.

Diagrammatic representation typifying the boiling water reactor power plant to be built by Mitchell Engineering, Ltd., in association with A.M.F. Atomics, Inc., of New York, for Rheinisch-Westfalisches Elektrizitatswerk A.G.

To prevent radioactive steam entering the generating plant a heat exchanger will be installed. A number of safety devices will be incorporated in the R.W.E. plant, including the automatic operation of control rods in certain conditions and the instrumentation will include apparatus to detect fuel element failure. The possibility of a rupture in the reactor vessel due to a power excursion will be remote but, should such a fault occur, the primary shield and a quenching system of room-temperature water to condense steam escaping from the reactor vessel will be designed to contain all radioactive material in the event of a "maximum credible accident," which is defined as the simultaneous rupture of the primary and secondary steam systems plus a very considerable nuclear energy release.

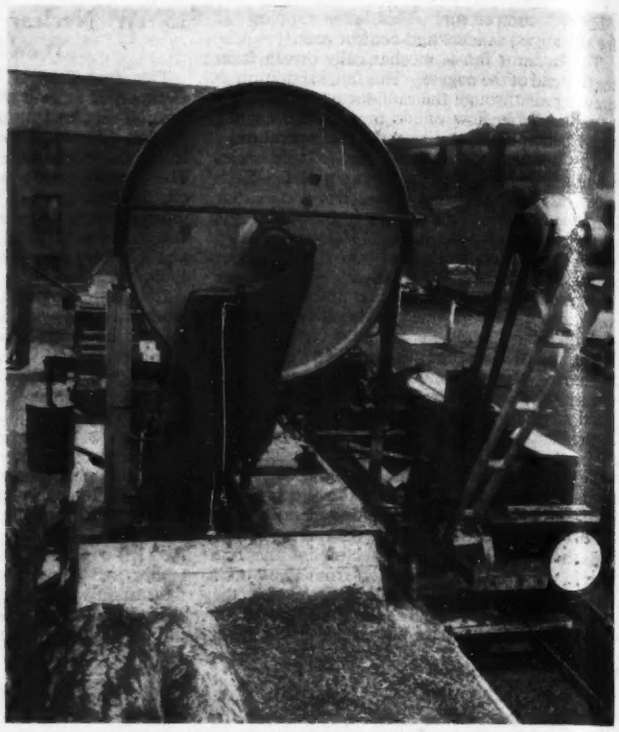
Because of the operating safety of the boiling-water reactor, the R.W.E. power plant will be situated only ½ mile from a populated area. The only radioactive waste from the plant will be resins collected on the ion exchange column, which will be used to keep primary water clean. About 2 cubic feet of this waste will be extracted every year and removed in a shielded coffin. Radioactive water from the primary circuit system will be kept in retention tanks for the normal "cooling off" period before being flushed in the normal drainage system.

The R.W.E. plant is designed for operation by engineers rather than scientists and only one qualified nuclear engineer—trained by A.M.F.—will be responsible for the whole operation of the station. Other key personnel needed will be given twelve weeks' training in the United States and a team of only ten men (three per shift) will be needed to keep the plant running for its estimated 8500 hours each year. Fluctuations in power use can be handled by the plant without damage to the reactor or components.

Two television cameras will be installed inside the reactor containment area to make visual checks on machinery while the plant is in operation. It will also be possible to lower a camera into the reactor vessel to monitor fuel element changing.

Portable Sawmill for Canada

This week-end there is being loaded for shipment to Canada a portable sawmill which has been designed and built by Stenners of Tiverton, Ltd. When used in the forest, very little site preparation is needed, and it is claimed that an output equal to a stationary mill of similar size may be expected. The vertical bandsaw, illustrated on the right, will deal with logs up to a maximum of 30in diameter by 18ft long. The sawmill is mechanised throughout, the power being derived from two diesel engines aggregating 166 h.p. The mill will normally be towed from site to site by a crawler tractor. The final trials of the sawmill were carried out at the manufacturers' works a fortnight ago; the complete mill has been built in about four months.

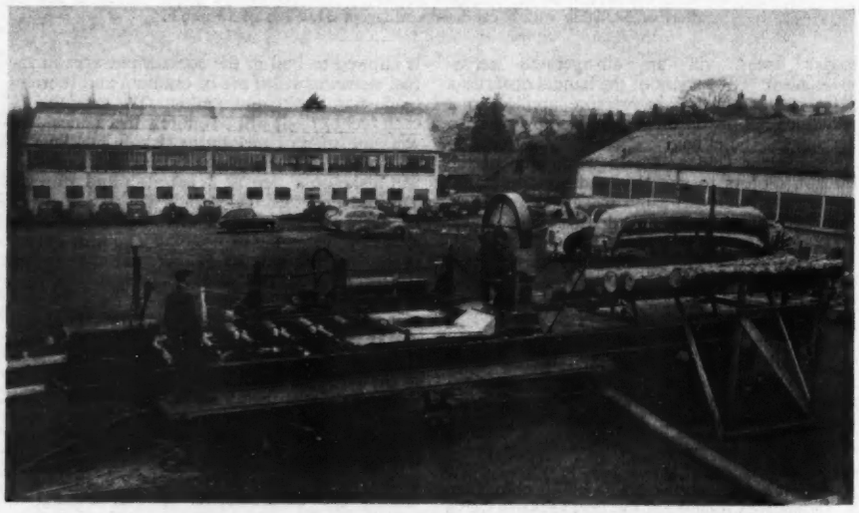


A PORTABLE sawmill which has been built by Stenners of Tiverton, Ltd., Lowman Works, Tiverton, for service in Canadian forests, has recently completed its trials. It is being loaded for shipment this week-end. The equiment, which is nearly 100ft in length when set up, has been designed to meet requirements specified by the purchaser, The Guelph Plywood Company, Ltd., of Mattawa, Ontario. The principal requirement was for a saw mill that could operate in those parts of a forest where stands of timber were not sufficiently large to support a stationary installation. Another matter taken into consideration was that, when road conditions prohibit the movement of wheeled traffic for certain periods of the year, the mill should be able to operate amongst felled timber, leaving the sawn lumber to accumulate until transport is possible.

The sawmill, which is illustrated herewith, will convert logs, up to a maximum size of 30in diameter and 18ft long, into finished timber ready for sale to a merchant. Three operatives only are needed—a sawyer, an edgerman and a trim saw operator. The equipment of the mill includes a vertical bandsaw headrig, a log carriage with mechanised handling, a log cleaning device, a three-saw edger, live and dead rolls for conveying the timber from the carriage to the edger, and a trim saw for squaring the ends and cutting boards to the required length. This trim saw and its conveyor are set up separately for the operation of the mill; when moving from one site to another they are carried on the trailer on which the remainder of the equipment is assembled. The trailer, which is built up of three longitudinal I-beams, 15in deep with 5in faces, is carried on two sets of pneumatic-tyred twin wheels, with the front towing axle on a deep sweep ring. When operating, the sawmill is supported by a series of blocking stands on the underside of the trailer chassis. The complete sawmill is powered by two diesel engines, a Rolls-Royce 120 h.p. and a Ford industrial 46 h.p. The former drives the air compressor, the headrig, hydraulic feed works motor and the sawdust exhaust fan, and the latter engine drives the edger saw spindle and an 18kVA alternator, which supplies the power for all the electrically operated equipment on the sawmill.

Normally, a fork lift truck will deliver the logs to the sawmill. A log deck, which is built on to the trailer chassis, comprises two log stops and two log loading arms which are mounted on separate shafts and operated by air cylinders. The log stops are operated by foot pedal and the loading arms by a hand lever. A set of "flipper" arms, mounted on the log carriage, are controlled by an air cylinder which is operated by a push button on the top of the feed works lever control. The high-speed log carriage is equipped with air dogging, electric set works and hydraulic feed works. The head blocks are traversed to and from the saw line by chain and pinions, the steel fabricated head block knees and slide units being mounted directly over each other. The dogs can be adjusted to and from the head block log face, and taper set gear, which is fitted to the first head block, permits a 2in movement on either side of the normal position. Incidentally, the taper setting and the adjustment of the dogs to and from the head block log face are the only manual operations necessary on this section of the sawmill. The electric set works are operated by a two-speed motor. The sawyer can set any dimension required and can repeat any selected dimension any number of times by the use of a "repeat" button, which is attached to the top of the feed works control lever. On the sawyer's control stand there is a setting dial which provides adjustment for varying saw kerf thicknesses, and on the head block nearest the sawyer there is an indicator dial which shows at a glance the distance from the head block face to the saw line. The hydraulic feed gear enables the carriage to be driven at a maximum speed of 525ft per minute.

The vertical bandsaw headrig has 48in saw pulleys mounted between oversized bearings, and carries a 7in saw. The steel fabricated baseplate is supported on two of the trailer beams. The cheek saw guides have bonded fibre pads which are adjustable individually to the face of the saw, and the top saw guides are raised and lowered by electric power. The normal speed of the saw exceeds 9000ft a minute, but a "quick-change" pulley can be fitted to give a lower running speed when frozen or tough timber is being sawn. An important adjunct to the headrig is a log cleaner; it is an electrically operated cutterblock which is brought down on to the top of the log just in front of the bandsaw, and which removes grit or any other foreign matter before the log encounters the saw. The frame which carries this cleaning device, with its built-in electric motor, can be seen to the right of the illustration of the headrig at the top of this page. Underneath the headrig there is installed a fan which operates the sawdust exhaust system



The sawmill ready for work. It is driven by a 120 h.p. engine situated under the log carriage and a 46 h.p. engine adjacent to the edger. The trim saw is not shown here

supplied by Dallow Lambert and Co., Ltd. In the layout of the mill, particular attention has been given to the positioning of the sawyer's controls. The control desk is situated on the sawyer's left hand ; on it there are mounted the set works indicator dial, the " fast forward " and " slow forward " push buttons for the electric set works, and switches for the electrical operation of the top saw guides and the air-operated dogs. As already mentioned, the hydraulic feed works of the log carriage are lever controlled, and at the top of the lever there are push buttons for operating the " flippers," the electric set works " repeat " movement, and for the " fast reverse " traversing of the head blocks. There are foot pedals for controlling the log deck stops and the log cleaner, and, close to the sawyer's hand, there is a shut-down switch for the main engine.

The edgerman takes over the pieces of cut timber from the sawyer. He can send a sawn board straight out of the mill on a " live roll " conveyor, or, with the aid of a pneumatically operated cross transfer, can bring the board to a " dead roll " edger conveyor. The live rolls, which are 6in in diameter, are chain driven from the feed works electric motor, and a stop is fitted in the live roll section to prevent the boards from leaving the sawmill until the edgerman has decided what to do with any particular piece. The edger, which will take timber 4in deep and 24in wide, carries three saws, one fixed and two sliding ; they are inserted tooth saws 20in in diameter. The saw spindle drive is taken from the 46 h.p. engine which is mounted adjacent to the edger, and the feed rolls are driven, through reduction gearing, by a four-speed electric motor, the speeds available being 40ft, 60ft, 80ft and 120ft a minute.

After the timber leaves the edger, all that remains to be done is for it to be trimmed and cut to length. The boards are passed on to a dead roll conveyor line, in the centre of which is mounted an electrically powered trim saw, 24in in diameter. The saw, which is raised into its work between two of the conveyor rolls by a spring-loaded hand lever, will cut a piece 16in wide by 4in deep. A fence plate is fitted at the back of the conveyor line and board stops enable the operator to cut any length of board from 8ft to 16ft in 12in steps.

In addition to the firms already mentioned, the following supplied various equipment for the sawmill :—Brook Motors, Ltd., motors ; The British Thomson-Houston Company, Ltd., and Muirhead, Ltd., switchgear and other electrical equipment ; Stein and Atkinson, Ltd., and Hamworthy Engineering, Ltd., hydraulic equipment ; Broom and Wade, Ltd., and Martonair, Ltd., compressed air equipment ; Charles Pitt (Barton Stacey), Ltd., trailer underworks.

Sixth Congress on Large Dams

THE sixth congress of the International Commission on Large Dams is to be held in New York from September 15 to 20, 1958. After the close of the congress there will be a series of study tours, giving participants an opportunity to visit dams in the United States. The following is the technical programme which has been arranged for the congress :—

Question No. 20 : heightening of existing dams, including methods of constructing new dams in successive stages ; Question No. 21 : Observation of stresses and deformations in dams and in their foundations and abutments, and a comparison of these observations with computations and tests on small-scale models ; Question No. 22 : Compaction methods and moisture content for materials used in the construction of the earth core and supporting fill for earth and rockfill dams ; Question No. 23 : Use of admixtures and pozzolanic materials in concrete for dams and the influence of the finer sand particles.

Offers of papers within the scope of one or other of these questions are invited from engineers in Great Britain by the Secretary of the British National Committee on Large Dams, whose address is 201-2, Grand Buildings, Trafalgar Square, London, W.C.2. Papers should be ready by the end of this year, but their scope and approximate length should be notified to the Secretary by June 30, 1957.

Heavy-Duty Planing Machine

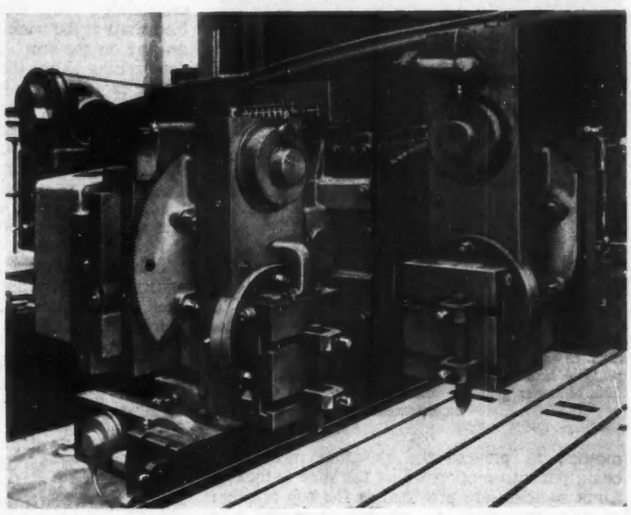
Particulars have been received from George Richards and Co., Ltd., of an interesting heavy-duty planer built by the firm to handle work up to 14ft wide, 10ft high and 30ft long. It can also be fitted with a cross planing head with a 12ft 9in stroke and a grinding head with a 20in wheel for surface grinding purposes.

A HEAVY-DUTY spiral electric planing machine recently completed at the works of George Richards and Co., Ltd., Broadheath, Altrincham, Cheshire, for William Asquith, Ltd., is designed to handle work up to 14ft wide, 10ft high and 30ft long. It has a 30ft long by 12ft 3in wide table and in addition to normal longitudinal planing is arranged for cross planing and surface grinding.

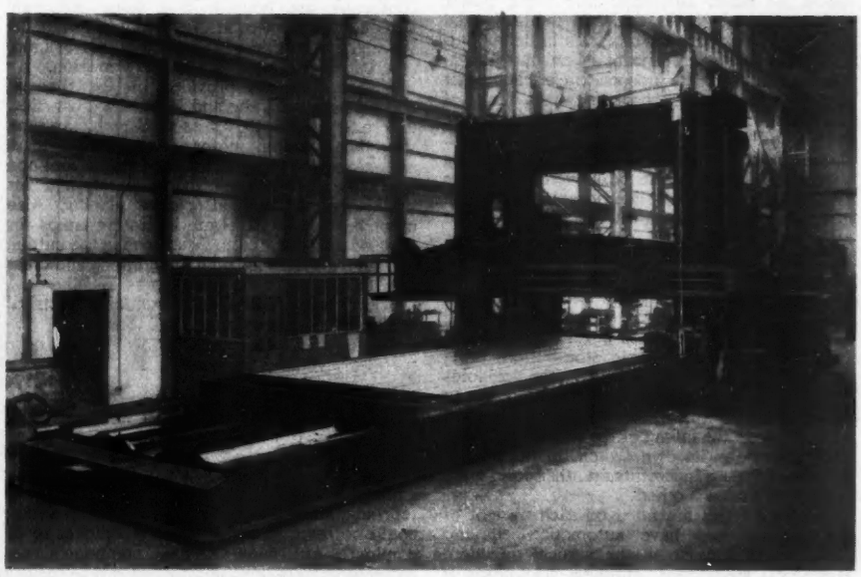
The table is fully supported over its full working stroke by a heavy box-section bed having four slideways each 60ft long and with an overall width of 11ft 6in. The table is of narrow guide design with a special strip for alignment adjustment purposes. Adequate lubrication of the bed slides and driving wormbox in the centre portion of the bed is provided by two motor-driven oil pumps. These pumps are interlocked with the main driving motor which cannot be started before the pump motors are running.

The machine is driven by an 80 h.p. variable speed d.c. motor from a Metropolitan-Vickers Ward Leonard set which was specially designed to give maximum performance in a reversing motor planer drive. Rapid acceleration and retardation are obtained by an auxiliary exciter, working in conjunction with a generator field, to provide very rapid reversal without imposing excessive stresses on the mechanical transmission. The motor output is 80/80/20 h.p. and it gives a speed range of 600/300/75 r.p.m. The table cutting and return strokes are controlled by independent rheostats, and a range of speeds from 10ft to 130ft per minute is available in both directions. The table drive is transmitted through a flexible coupling to a worm reduction box employing a steel worm which drives a phosphor bronze wheel on the oblique table spiral pinion shaft. At its inner end this table shaft carries a spiral pinion which meshes with a cast iron rack on the underside of the table, the thrust in driving being taken by heavy-duty double-ball thrust washers.

The cross-slide is particularly deep on the main slide and increased depth where it fits the uprights eliminates deflection and counteracts the torsional stresses set up in heavy-duty cutting. This cross-slide is counterbalanced and is locked on the uprights by a $\frac{3}{4}$ h.p. motor at each end between the uprights. Each of these motors operates through suitable gearing two clamp plates which bear on the inner square lock of the upright, one at the top and the other at the bottom of the cross-slide. The locking



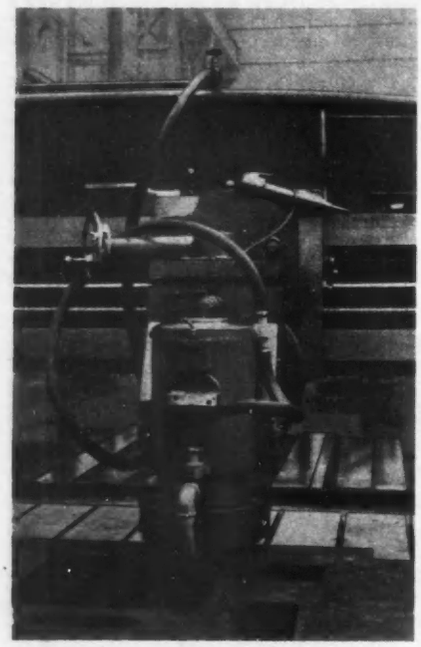
Detachable cross planing head fitted on saddle extension of left-hand planing head. This cross planing head can be swivelled through 90 deg. and used for deep cross planing. The cross planing stroke is 12ft 9in long



Heavy-duty planing machine with a 30ft by 12ft 3in table and capable of taking work up to 14ft wide, 10ft high and 30ft long. It is also equipped for cross planing and surface grinding

motors are controlled by push buttons and indicating lamps are provided on the control cubicle. When the locking operation is completed. These motors are free to reverse when the unlock button is pressed and are interlocked with the main motor to prevent the table being put into operation while the cross-slide is unlocked.

Raising and lowering of the cross-slide is actuated by a 9 h.p., 500/1250 r.p.m. motor which provides power for the tool box feed and rapid power traverse motions. This motor is also interlocked with the cross-slide clamping



Surface grinding attachment fitted to right-hand planing head of machine. This attachment has a 20in diameter grinding wheel and a coolant system is incorporated

motors, to prevent the elevating mechanism being put into motion whilst the slide is locked. Limit switches are provided at the top position of the cross-slide to prevent over-run and similar provisions are made for the bottom limit of the side tool boxes and to prevent collision of the cross-slide and side tool boxes.

The two tool boxes on the cross-slide have means of hand, automatic and rapid power traverse in both the vertical and the hofizontal directions. A worm and quadrant in the mountings of the slides give means of angular adjustment. The heads are independent of each other and their feed box mechanisms give a range of fine feeds from $^1/_{96}$ in to $\frac{1}{4}$in, and a range of coarse feeds from $^1/_{32}$in to $\frac{3}{4}$in per stroke of the table. These feeds apply to the cross-slide boxes horizontally and the side boxes vertically. The feed ranges of the cross-slide boxes in the vertical direction are half those provided for the vertical movement. The coarse feed range also applies to cross-slide vertical movement.

On the return stroke the tools on the boxes are lifted by means of solenoids which operate at the end of the cutting stroke and remain energised until the tools are ready to begin cutting again. In the event of the table stop-button being pressed during the return stroke, the solenoids remain energised, thereby preventing damage to the tool or workpiece, which would otherwise occur through the falling of the tool. Each head is controlled by its own switch on the cubicle and the lifting arrangements are, therefore, quite independent of each other.

Side tool boxes are fitted on each upright of the machine and have automatic feed and rapid power traverse in the vertical direction. Horizontal adjustment of these side boxes is by hand and they are equipped for tool lifting by solenoids. The 9 h.p. elevating motor of the cross-slide also provides the power for the tool box feed and rapid traverse movements.

A detachable cross planing head can be mounted on a saddle extension of the left-hand planing head and this head has a stroke of 12ft 9in from the inside face of the left-hand upright. This attachment can be seen in one of our illustrations and it is driven by a 15 h.p. motor and a special driving box fitted to the left-hand side of the cross-slide. Motion is transmitted to the cross planing head through a screw running the length of the cross-slide and engaging nuts on the saddle. The length of stroke is controlled by a large dial carrying adjustable dogs engaging with a reversing switch, and a safety switch is provided to prevent accidental over-run.

The electrical equipment of the machine includes a changeover switch to control either the longitudinal or cross planing as desired, and this switch acts as an interlock between the longitudinal and cross planing motions. For longitudinal planing the direction of the main motor and the operation of the feed motor are controlled by the table reversing switch operated by adjustable dogs on the table.

The feeds to the cross planing head are provided by the feed box used for longitudinal planing and the feed rates for both motions are the same. These rates are indicated on the dial on the feed box. The cross planing feed driving shaft is driven by the down feed shaft in the cross-slide; from this shaft mitres connect the feed shaft at the back of the cross planing arm to gearing on the arm. Selector gears are used for determining either the cross or the vertical feed to the cross planing head. Electrical interlocks are incorporated to prevent conflicting motions operating at the same time and, as in the case of the normal heads, tool lifting for the cross planing head is actuated by solenoid.

A counterbalanced cross-slide is fitted for the first time on a Richards planing machine and in this case is primarily designed to steady the cross-slide as it commences the deep cross planing operation. Balancing also materially assists in the elevating of the cross-slide. During deep cross planing the tool slide on the cross planing attachment is swivelled 90 deg. from the vertical position.

A "Snow" grinding head having a 20in diameter grinding wheel is interchangeable with the right-hand planing head for surface grinding purposes. It is fitted to the machine by removal of the normal planing head, when it can be attached to the saddle by means of an adaptor plate. A coolant system is provided and the cutting lubricant is drawn from tanks through a filtering system; after use, the coolant is returned to the tanks via a drain fitted to the table.

Movements of the machine are controlled from a twelve-point counterbalanced pendant push-button station. The main control and feed contactors are housed in a floor mounting cubicle and the rheostats are arranged in a panel situated at the side of the main planer column, adjacent to the operator's working position.

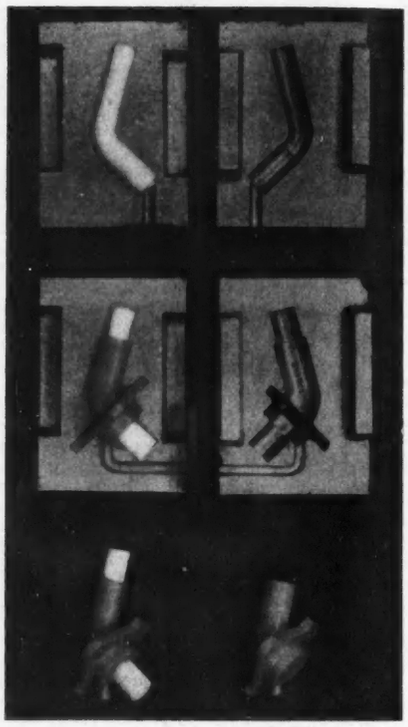
Push buttons are provided on the rheostat control panel, to raise and lower the cross-slide, lock and unlock the cross-slide and start and stop the oil pump motor. In addition, there are on and off switches for each of the tool box solenoids, for stopping the m.g. set, and for selection of longitudinal or cross planing. Also mounted on this panel are indicating lamps for the feed and m.g. set and dials giving the cutting and return speeds for both longitudinal and cross planing.

The weight of the planer, excluding electrical equipment, is approximately 190 tons.

Soluble Wax Cores for Investment Casting

THE technique of lost wax casting is frequently employed not so much for its accuracy in reproduction as because it allows shapes that could not be attained by other techniques to be employed. In many cases the components are required to be hollow, and this has led to the use of complicated cores built up in several pieces, or even to making the wax model in two or more parts and sticking them together, a process which invariably marred the casting. In some cases the design could be compromised to allow the cores to be simply removable, as by having a perfectly toroidal passage or one with a sharp corner. A technique now in use by Firth Vickers Stainless Steels, Ltd., Sheffield, gives a considerable measure of freedom in shaping internal spaces, since the core is removed by dissolving it. While the core will itself require to be cast, any limitations this lays upon its shape are mollified by the fact that the core can be carved after casting and before use.

The material used for the cores is polyethylene glycol, which melts at 49 deg. Cent.; if desired, it can carry a dispersion of powdered metal or zircon to increase its thermal capacity. It is a material which contracts markedly on cooling, and thicknesses greater than $\frac{1}{4}$in are to be avoided; thus, the mould for the core may itself have a core, either metal to accelerate solidification or wood or rubber for cheapness—the shape of such a core is, of course, not critical, since it is only the outer surface which is required to be defined. Because the material is not easily cast, massive metal moulds are used; no parting agent is required, except possibly on a core if one is used. The temperature of the liquid wax is critical, the appearance of "crocodile skin"

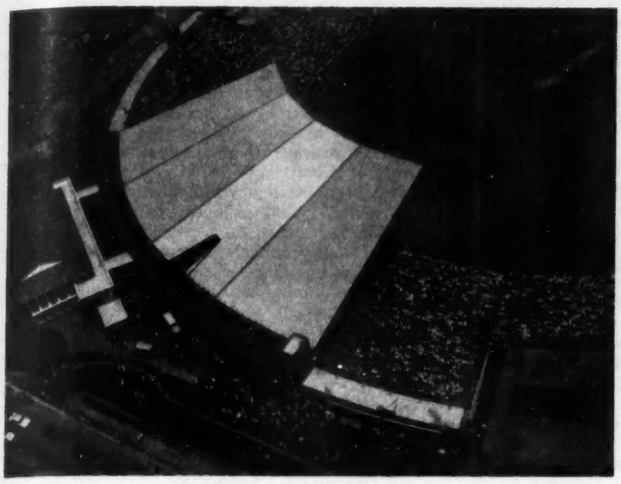


Soluble wax core shown, top, in its own mould, centre, in place as a core, and bottom, before and after dissolving out of wax model

resulting if the wax remains liquid against the walls of the mould, and mechanised injection is probably desirable for working it.

The soluble wax casting is then placed as a core in the mould for the wax pattern. Firth Vickers inject the wax into the mould when it is in a partly liquid state at a temperature of 55 deg. Cent., relatively high pressures up to 1200 lb per square inch being required. The heat transfer values for wax are so low that the core does not lose its shape, nor does it fuse into the solidifying wax. The wax patterns are then immersed in cold water, overnight if pure water is used, or for a much shorter period if soda-ash has been added to the water, which will generally be the case if mineral fillers are included in the soluble wax.

The accompanying illustration shows, top, the mould for the soluble core, centre, the wax pattern in its cored mould, and, bottom, the wax pattern before and after the core has been dissolved.



Aluminium alloy building sheet roof on the new grandstand at the Wanderers' Club cricket stadium, Kent Park, Johannesburg. (Right) Laying the aluminium alloy building sheet roof on the grandstand.

Aluminium Grandstand Roof

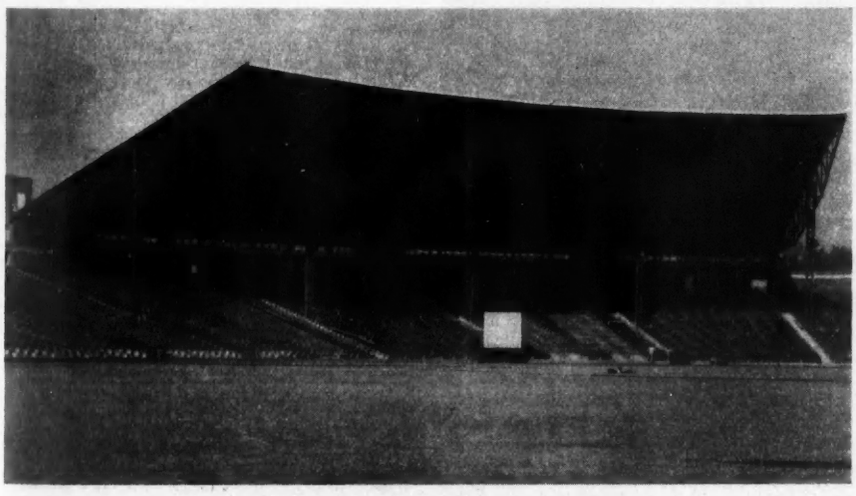
BY OUR SOUTH AFRICAN CORRESPONDENT

THE new grandstand at the Wanderers' Club Cricket Stadium in Kent Park, Johannesburg (Fig. 1) has many impressive features, but one of the most interesting is the aluminium-clad roof. Designed by R. C. Rinaldi and Partners, in conjunction with Heney and Trevorrow, consulting structural engineers, the stand comprises a semi-cantilever construction measuring 135ft from back to front with an unsupported portion of five open braced columns at the front. One of the major factors enabling this large overhang to be achieved, through making lighter the whole structure, was the choice as roofing material of ACOSA "Industrial" aluminium alloy 20 S.W.G. (0·036in) building sheet, produced in Pietermaritzburg, Natal, by the Aluminium Company of South Africa (Pty.), Ltd. This material is not only light, but also by reason of its deep-ridged design, strong enough to cover the wide spans. In this instance, steel purlins were placed at 8ft 3in centres, with a consequent reduction of nearly 4 tons in the weight of purlins required, compared with that necessary to support conventional heavier roofing material. Construction in progress can be seen above.

The consulting engineers have given their reasons for choosing ACOSA "Industrial" sheeting in preference to other roofing materials as follows. The design of the sheet permits a larger rain-water run-off than any of the other sheet profiles considered ; in fact, two and a half times the amount of water can be disposed of compared with a sheet possessing the normal circular corrugated profile, so avoiding the necessity of incorporating unsightly gutters halfway down the slope ; the aluminium roofing will require no painting and this, over a period of years, will mean a considerable saving in maintenance costs ; the expected long trouble-free life of this light alloy sheeting is high ; and aluminium sheeting of this profile has a pleasing appearance.

The sheeting, which was erected by Scaffolding (G.B.), Ltd., is able to withstand with safety a load of 200 lb on a 5in square. Walking on the sheet during erection thus involves no danger, and the narrow crests of the corrugations are specifically designed to resist denting by the boots of erection or maintenance parties. The general design of the structure can best be seen below.

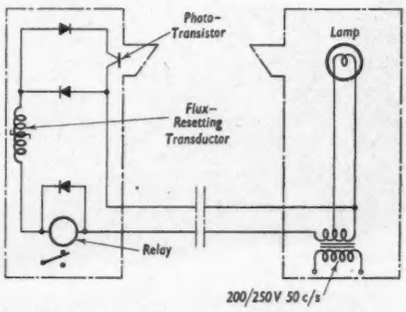
There is no doubt that this new light alloy roof has been conspicuous, for many comments have already been heard about its brightness. However, it is a characteristic of aluminium that it soon weathers to a pleasant matt bluish-grey colour, so eliminating the glare that is found the first few months after erection. The heat-reflecting properties of this new kind of roofing material are not appreciably reduced by this weathering, and spectators watching matches this summer from the grandstand have experienced to the full the advantages of this aluminium roof in maintaining cooler conditions. The experience that has been gained in the construction of this unusual roof may well lead to increased interest in the use of aluminium for this kind of cantilever design, or for any roof where the aim is to cover a large area while keeping weight and maintenance costs to the minimum.



Grandstand as seen from field of play

Photo-Transistor Relay

A PHOTO-TRANSISTOR relay has been developed by Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester, and it can be seen at the Electrical Engineers (A.S.E.E.) exhibition, which closes at Earls Court tomorrow. This equipment, which is known as the "Magistor," is a photo-electric relay intended for use instead of mechanical limit switches in situations where it is not permissible or possible to touch the initiator and where the speed of operation of a mechanical switch may lead to wear and failure. Typical applications are counting, level control, warning devices, height gauges, door control, smoke detection, inspection,



Simplified circuit of photo-transistor relay

edge position control, material handling, sequence checking and sorting.

The "Magistor" relay dispenses with the need for thermionic valves, large photo-electric cells and h.t. supplies.

As illustrated in the accompanying diagram the equipment consists of two small units, a lamp box and a receiver. The lamp box contains a transformer supplying a prefocused lamp, whose light passes through a lens to produce a parallel beam, which is directed to the receiver unit, where it is focused by a lens on to the photo-transistor. The output of the photo-transistor energises a flux-resetting transductor, which controls a relay having change-over contacts. The relay operates when the light beam is broken.

The photo-transistor used in this circuit is a germanium-junction transistor, which is light-sensitive, has small dimensions (¼in diameter by ½in long), high sensitivity, and low-voltage

operation. The flux-resetting transductor is simply a choke wound on a core of special material, whose impedance can be varied by the action of the applied voltage during the reverse half-cycle ; thus it responds to applied signals in approximately one hundredth of a second on a 50 c/s supply. The circuit is so arranged that the transductor has very high impedance when light falls on the photo-transistor and a very low impedance when the light beam is interrupted. The transductor is connected in series with the relay coil across an external supply and acts like a magnetic switch, closing the circuit and energising the relay whenever the light beam is cut off. The power consumption is only 16W and the interconnections consist of two wires.

The " Magistor " photo-transistor relay can also be supplied with electrical counters for speeds of up to ten per second. Batching counters are available to deal with at any predetermined quantity.

Mobile Workshops for Servicing Power Station Equipment

THE first of two mobile workshop equipments for the repair and servicing of turbo-alternator sets at power stations has just been put into operation by the British Thomson-Houston Company, Ltd., Rugby. These units have been developed with a view to speeding repairs in this country, relieving the pressure of work on the firm's parent factory, and to providing an after-sales service overseas. With these new facilities all normal adjustments and repairs to sets can be carried out at any power station requiring the service by factory-trained personnel. In the normal way, when parts are returned to the factory, delays occur whilst they are waiting between operations due to the need for dovetailing new construction with the repairs on the same machines, such as large lathes and balancing equipment. By carrying out the work at the power stations concerned and avoiding transport of worn parts to the main factory, much time can be saved and a generating set is kept out of commission for a shortest possible period.

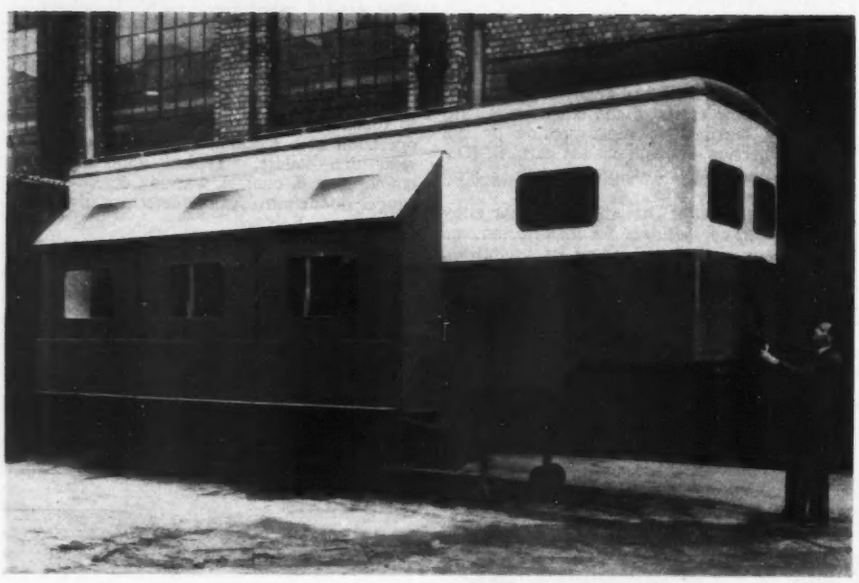
The two main items of equipment in a mobile workshop comprise a specially designed lathe which can be transported about the country on a low loader or in lorries where road conditions limit loads, and a mobile caravan trailer vehicle, to be seen in the illustration on this page. The lathe comprises a baseplate in two halves which can be bolted together ; a headstock, complete with motor drive, steady bearings and a tailstock. It is designed for assembly on a concrete floor, such as in a power station basement, where the complete machine can then be levelled by use of six jacks arranged down each side of the base. The lathe has been designed to swing rotors up to the size of an l.p. rotor for a 120MW set. It will be used for checking rotors for truth, machining out damaged blades, threading replacement blades, machining the blade roots after assembly and turning banding to give the correct clearances in the turbine.

The workshop is designed to stand outside a power station, and it has sides which can be opened out to give a reasonable working area. It is equipped with three milling machines, all of which are necessary at one time for milling low-pressure rotor blade roots to match the wheel grooves ; a surface grinder and other small tools. Two pedestal equipments carried in the workshop can be used to carry out static balancing of a completed rotor. These pedestals will be mounted on the bottom half casing of a turbine when balancing is being carried out. In connection with these pedestals it was considered that, providing a machine was in reasonable balance before going out of service, then static balancing should be adequate to ensure a satisfactory running job.

Although the workshop has been made as self-contained as possible it will still be necessary to make use of the equipment of the parent factory. Such things as hydraulic jacks have not been provided for pulling off couplings and wheels, and when required will be loaned from the factory. Punching of the banding for the blades is also still being carried out in the factory, but is hoped later to provide suitable equipment in the workshop.

When the mobile unit arrives at a power station the only assistance which will be required will be access to the station crane for unloading equipment and to facilitate the lifting of the rotor in and out of the lathe. For driving the equipment a three-phase power supply will also be necessary, the lathe requiring 14A at 400V to 440V, and the workshop 20A at 400V to 415V.

To staff the unit men have been under training with factory personnel in the main works of the company for over twelve months, and initially three men will be allocated to a unit. The planning of the workshop has been based in the first instance on the necessity for reblading rotors, but, as experience is gained, it is hoped that a wider range of work will be possible. Such work as the machining of turbine wheels and the truing up of thrust collars should be possible, but the success of these operations will depend upon the accuracy to which machining can be carried out. In the past, the production of blades has been a limiting item in most repair work. With the advent of blade manufacture at the company's Larne works, this problem is rapidly diminishing so that blades will be available in a reasonable time for the unit.



Workshop of mobile unit for servicing power station alternator sets on site

Efficiencies of C.E.A. Power Stations

THE Central Electricity Authority states that last year nearly a million tons of coal—960,000 tons—were saved in the power stations of the Central Electricity Authority in England and Wales by increased efficiency of operation. The overall average thermal efficiency during the twelve months was 24·70 per cent, compared with 24·14 per cent for the previous year.

Nearly 75,000 million units were supplied from these stations and over 30 per cent of that output was provided by the twenty most efficient stations operating throughout 1956. These twenty stations had an average efficiency of 28·91 per cent, their individual efficiency percentages being :

Stations	Thermal efficiency, per cent
Littlebrook " B," Dartford, Kent	30·62
Drakelow, Burton	30·54
Stourport " B " L.P., Worcs	30·08
Stourport " B " H.P., Worcs	30·05
Stella South, near Newcastle upon Tyne	29·70
Barking " C," London	29·40
Dunston " B II," Newcastle upon Tyne	29·33
Stella North, near Newcastle upon Tyne	29·16
Ince, near Ellesmere Port	29·02
Skelton Grange, Leeds	28·81
Keadby, Scunthorpe	28·70
Brunswick Wharf Poplar	28·68
North Tees " C," Middlesbrough	28·60
Littlebrook " C," Dartford, Kent	28·55
Carrington, near Manchester	28·46
Bromborough, Cheshire	28·44
Brighton " B "	28·36
Battersea " B "	28·30
Deptford East H.P.	28·24
Poole	28·24
Portishead " B," near Bristol	30·00
Wakefield " B," Yorks	29·26
Hams Hall " C," near Birmingham	28·91
Meaford " B," Stone, Staffs	28·72
Marchwood, near Southampton	28·38

The last five stations listed above did not come into operation until after January 1, 1956, but nevertheless recorded high efficiencies during the period they were working.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

TENSILE TESTING OF METALS

No. 18 : 1956. Price 4s. In preparing the fifth revision of this standard the aim has been to describe and define all procedures relating to tensile testing which are common practice throughout industry or, in certain instances, within large branches of industry. It now includes two proportional test pieces, which may be of circular, square, rectangular or hexagonal cross-section, with gauge lengths equal to four times and 5·65 times the square root of the cross-sectional area of the parallel portion. They are two of the test pieces recommended by the ISO technical committee on steel.

Non-proportional test piece *A*, used chiefly for sheet, plate, strip, flat bars, sections and tubes, has been retained, and there are references to test pieces *A1*, *B*, *B1* and *C*, which were specified in the earlier editions of the standard. Requirements specified for test pieces for tubes relate to the testing of the tube whole, or when strips are cut longitudinally or circumferentially from it, or when the test piece is turned from the wall of a thick tube. Test pieces for wire are also dealt with.

A section dealing with standard methods of procedure for tensile testing includes a revised clause on proof stress and new clauses on permanent set stress and proving tests ; other clauses deal with yield, tensile strength and percentage elongation. Terms used in the tensile testing of metals are defined, and one—" tensile strength "—has been adopted in place of " ultimate tensile stress." Detailed description or definition of procedure which is related to specific materials has been avoided, but the foreword lists—as a guide to committees engaged in the draughting or revising of standards for materials—points which may need to be separately specified for each material.

FASTENING THREADS OF B.S.P. SIZES (FORMERLY IN B.S. 84 : 1940)

No. 2779 : 1956. Price 5s. Requirements for the dimensions of the fastening threads specified originally in B.S. 84, have been transferred to this new British Standard to avoid misunderstandings as to their application. It deals with fastening threads of B.S.P. nominal sizes from ¼in to 6in inclusive. In it " close " and " medium " class tolerances are specified for external and internal threads, " free " class for external threads and " normal " for internal threads. The tolerances on these threads are such as to make them unsuitable for joints where a pressure-tight seal is made by the mating of the threads themselves.

Industrial and Labour Notes

Employment and Unemployment

There was a drop, during February, of 31,000 in the number of people in civil employment in Great Britain. At the end of the month, the total was 22,948,000 (15,213,000 men and 7,735,000 women).

The Ministry of Labour's latest report on employment shows that of that total there were 3,959,000 at work in the basic industries in February, an increase of 11,000 compared with a month earlier. The greater part of the increase occurred in transport and agriculture, though in mining and quarrying the rising trend in employment continued, and there was an addition of 2000 to the labour force. But in the manufacturing industries there was an overall decline of 24,000 in the labour force during February, the total at the end of the month being 9,189,000, compared with 9,352,000 a year ago. Most of the manufacturing groups were involved in the decrease. In the engineering, metal goods and precision instruments group there was a drop of 8000, making a total of 2,798,000 at the end of the month. In vehicle building the number employed fell by 5000 to 1,192,000. In the industries and services outside manufacturing, one of the principal changes in February was in building and contracting, where the number employed fell by 8000 to 1,494,000.

The latest published figures about unemployment show that on March 11 there were 362,945 people (about 1·7 per cent of the total number of employees) registered as out of work, compared with 380,060 on February 11. The March figure includes 27,592 who were temporarily stopped. The Ministry says that an increase in the number described as "temporarily stopped" followed a change at the end of February in the guaranteed week in the engineering industry, whereby certain workers on short time who were formerly ineligible became able to receive unemployment benefit and so found it worth their while to register as unemployed. The Ministry's report also states that, in the week ended February 23, there were 1,500,000 workers on overtime in manufacturing establishments, which was 103,000 fewer than three months previously. In the same week, the number working short time was 109,000, which was 37,000 less than a month previously.

Railway Wages

The British Transport Commission has stated that members of the Associated Society of Locomotive Engineers and Firemen employed on British Railways are to receive a wage increase of 2 per cent to bring their total increment into line with the 5 per cent accepted by the National Union of Railwaymen and the Transport Salaried Staffs Association. The A.S.L.E.F. agreed to accept a 3 per cent increase last November, before settlement was reached on a claim submitted by the N.U.R. A fortnight ago, the Commission reached agreement with the N.U.R. for a 5 per cent increase, the agreement being coupled with an undertaking concerning measures for increasing efficiency and periodic reviews of wages and other matters.

The executive of the A.S.L.E.F., however, was not prepared to participate in the 5 per cent increase on those terms, and is still considering its next approach. The Commission has said, meanwhile, that it is not practicable to distinguish between individual members of the staff according to the unions to which they belong. Moreover, it adds, it does not desire to penalise particular members of a loyal team because of a failure to reach agreement with one union. The Commission's statement ends by expressing the hope that "in the forthcoming discussions of the problems of efficiency and stability to which the agreements with the other two unions have referred, the A.S.L.E.F. will make a practical contribution, and so permit the restoration of a normal and harmonious relationship between the Commission and all three unions."

Trade Unions and Management

Last week-end, the British Institute of Management held a conference at Droitwich, the general theme for the discussions being "Meeting To-morrow's Problems." One of the papers, entitled "A Trade Union Viewpoint," was presented by Mr. S. C. Hills, a regional secretary of the Transport and General Workers Union.

Mr. Hills urged that the trade unions should have a greater voice in the management of industry. Some managements, he said, had used joint consultation merely because a full employment situation made the "hire and fire" maintenance of works discipline impossible. In such cases, Mr. Hills claimed, joint consultation could not be successful. But, he continued, where managements had decided that in a political democracy industrial autocracy was impossible and undesirable, and where it had been realised that human beings were not to be treated as machinery, then consultation had been successful. Mr. Hills went on to say that the workers' desire for a "square deal" must inevitably be related to the economic condition of the country, and by now there was universal acceptance of the necessity for the most effective use of our resources. Work study had been carried out in a wide range of industries, necessitating redeployment of labour and the exercising of new skills and responsibilities. Automation had been generally accepted and the consequential adjustments made through the usual negotiating and consultative machinery. It was true, Mr. Hills observed, that in an expanding economy change had been facilitated, but the acceptance of change by the workers marked a distinct advance from their traditional resistance to innovation. Any return to the inter-war employment situation, however, would revive the traditional outlook, Mr. Hills said, and those who had thought that "some unemployment would be economically advantageous" should think again.

Mr. Hills went on to say that mobility of labour could only be secured if general social conditions, such as housing and education, were satisfactory, and that, he urged, was not just a problem for industry. It had yet to be shown, he remarked, that "taking work to the workers" was a bad policy, economically and socially.

Education and Training

Another paper discussed at the conference mentioned in the preceding note was one on "Education and Training," by Mr. C. L. Old, principal of the Wolverhampton and Staffordshire College of Technology. He suggested that the education and training needs of industry were being neglected because of the present structure of the educational system in this country. There were three fundamental reasons, Mr. Old said; first, costs were borne nationally, but also by the ratepayers and those elected to local councils were sensitive to increases in rates; secondly, the governing bodies of many technical colleges had a preponderance of local government representatives who were not wholly sympathetic to the needs of industry at the higher levels, and, thirdly, the education service as such was tuned for educating the man rather than preparing him for a vocation.

Mr. Old went on to examine in some detail systems of training for craftsmen, technicians and technologists. About training for craftsmen, he suggested that where at all practicable training workshops should be provided so that apprentices were under the influence of instructors who were picked for the job. He urged also that the principle of indentured apprenticeships should be revived and conditions incorporated requiring graded tests and attendance at courses of instruction in related science, either within the works or at a technical college. To these suggestions, Mr. Old added that the basis of craft training should be broadened and that training should be based on job analysis. In other words, Mr. Old said, there should be a previous breakdown of training into the fundamentals of a craft, and those fundamentals should be as broad as possible.

It was recognised, Mr. Old commented, that many suggestions of this kind might meet with opposition from the trade unions, but if their actions operated against good training they were restrictive practices and should be plainly labelled as such. Enlightened trade union leaders, Mr. Old said, would not object to good training, for their concern was with the interests of their members and that must, in the long run, involve the best interests of the nation of which their members formed a part.

Coal Production

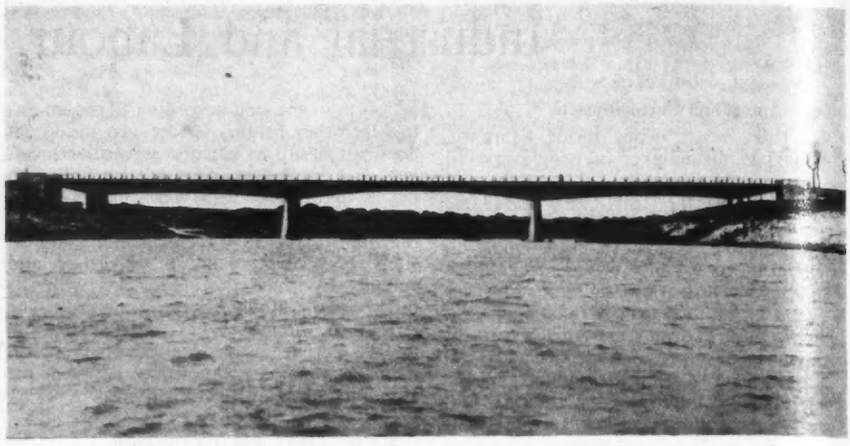
The improvement in this country's coal output, which has been noticeable since the beginning of the year, continues. Deep-mined coal production is now over 3,000,000 tons ahead of the comparable figure for last year and opencast output is about 500,000 tons up. In the first fourteen weeks of this year, ended last Saturday, total output amounted to 64,780,700 tons, there being 61,520,900 tons from the deep mines and 3,259,800 tons from opencast sites. Comparison with the corresponding period last year, however, is not quite valid as the Easter holiday last year came into the total for the first fourteen weeks.

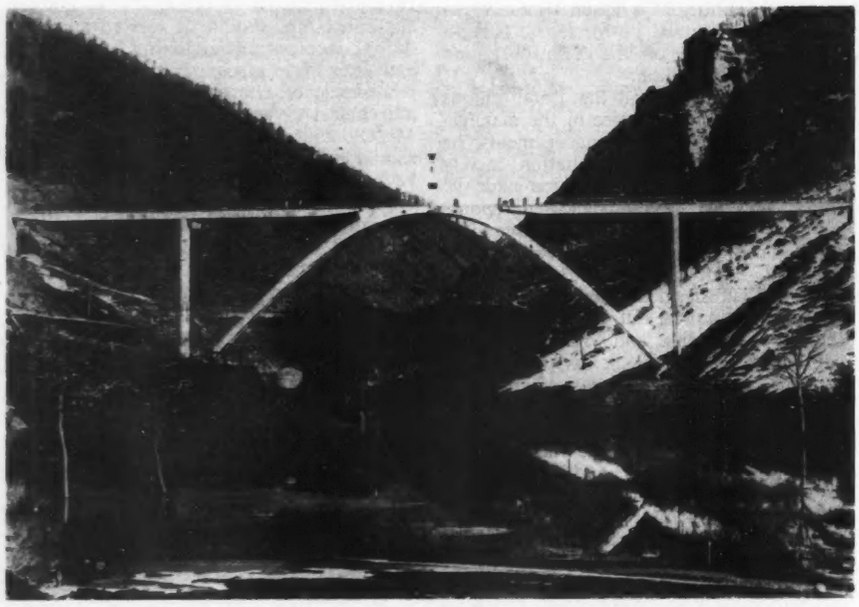
The overall manpower position continues to improve and at the end of March there were 711,200 workers on colliery books, compared with 705,100 a year earlier. The number of faceworkers, 286,900, was, however, 1100 below the number at the end of Mareh, 1956. Output per manshift is higher than it was a year ago, and there is slightly less absenteeism.

Coal consumption so far this year has been lower than in 1956. In the first thirteen weeks, it totalled 62,814,000 tons, of which only 2,215,000 tons went to exports and bunkers. In the same period, 920,400 tons of coal were imported, or about half the quantity imported in the corresponding period last year.

Concrete Bridges

The need to replace the many bridge structures destroyed in the war gave a strong impetus to design, and in particular to the development of reinforced and prestressed concrete techniques. We refer opposite to a recent lecture by Dr.-Ing. Riccardo Morandi, in which he described a number of his own designs in this field, among them the structures which we show on this page. On the right may be seen the Grillo bridge, over the Tiber, in Rome, which is one example of Gerber beams using high-strength concrete and ordinary reinforcement. The main spans are 160ft and the quantity of concrete is about 1·65 cubic feet per square foot of deck, said to be an average figure for this kind of design which has become commonplace in Italy in recent years. Adoption of prestressing here brings an immediate advantage, lowering this ratio which, with reinforced concrete, is never better than unity, to about 0·6 to 0·7





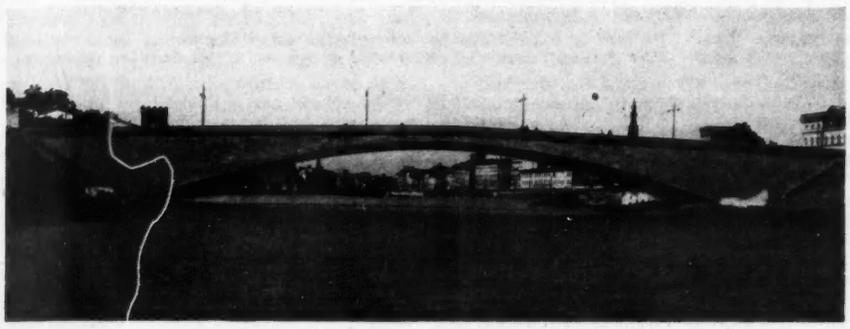
The Vagli di Sotto bridge, in Tuscany (left) is a footbridge over a reservoir. It has a span of 230ft, formed by a three-hinged arch in normal reinforced concrete with the roadway in prestressed concrete. The great height between the bed of the basin, as well as the nature of the ground, would have necessitated very elaborate centering. Moreover, the reservoir was scheduled to be filling while the bridge was still being built, so that removal of the submerged portions of the centering would have been difficult. With the method of construction actually adopted, the two half-arches were cast lying on the sides of the mountain and then rotated into position. (This method was used in 1949 by Krall for the centre of the Sciafarday bridge over the Blue Nile.) In order to avoid the need for duplicating the winching gear, the two halves were rotated one after the other, the first being supported temporarily on a central tower built from tubular scaffolding. As the handling stresses in the concrete would have been excessive, and would have required an uneconomical section and extra reinforcement, resort was had to a method of temporary prestressing whereby the handling stresses were absorbed

In recent years two road bridges, practically identical, have been built, each with a span of 390ft. Of these, the Lupara bridge (between Genoa and Savona) was designed by Morandi; the other, the Caifa bridge, on the Pompei-Salerno highway, by Maillard. In the case of the Lupara bridge (right) the quantities of concrete and steel per square foot of deck were 3·15 cubic feet and 22·5 lb respectively, while for the Caifa bridge the figures were 4·35 cubic feet and 28·5 lb. The Lupara bridge was constructed with the help of metal centering, using about 200 tons of steel. Special provision was made to allow a gradual striking of the centering so as to induce the stresses in the arch due to its own weight as gradually as possible. Another system of shuttering which is becoming popular in Italy is the Cruciani timber shuttering, which in recent months has been used for arches spanning over 300ft, and was described in "The Engineer" of November 4, 1955

Modern Concrete Bridges

IN his lecture, given in London on March 19, at the invitation of the Joint Committee on Structural Concrete, Dr.-Ing. Riccardo Morandi spoke on the theme "Modern Conceptions in the Planning of Bridges in Reinforced Concrete and in Prestressed Concrete." Paying tribute to the many fine arch bridges of the past, Dr. Morandi showed how modern techniques have made possible the conquest of great spans with concrete bridges having shallow arch rises. The chief aim had been continually to reduce the dead load in relation to the carrying capacity, and success in this direction was such that spans of 600ft and more had been built recently.

The demands of post-war reconstruction in Italy have provided the stimulus and the opportunity for the development of concrete bridge design. Dr. Morandi gave examples from his own work to show the gradual refinement of the solution of a design problem, the designer benefiting from his own experience and that of others and from developments in concrete technique. In this way arches of continually increasing span, lightness and economy have been achieved.



San Niccolo Bridge, Florence. Single arch span of 290ft, rising 26ft. Cellular arch, 3ft 6in deep at crown, 11ft 6in at the springing. Top and bottom slabs are 1ft thick throughout, except for bottom webs near the springing

For the San Niccolo Bridge in Florence, in 1946, a cellular structure 3ft 6in deep at the crown and 11ft 6in at the springing was used as illustrated. This showed considerable economy, particularly as regards reinforcement, compared with more conventional designs with stiffening diaphragms which were also submitted. The arch is a cellular structure of an overall depth of 3ft 6in at the crown and of 11ft 6in at the springing, with a bottom slab 1ft thick throughout most of its length, except that near the springing a series of webs are placed at centres of about 10ft and top slab of a constant thickness of 1ft.

The cellular structure projects beyond the springings for about 112ft and constitutes a box-like element supported by a pile foundation consisting of hollow piles inclined at a suitable angle, filled with a mass of sand and gravel, used to contain the resultant of the forces on the level of the foundation within an angle of 32 deg. with respect to the vertical. Excluding the foundations, 3·28 cubic feet of concrete and 24·8 lb of mild steel were used per square foot of road deck. The behaviour of the bridge at the striking of the formwork, during tests and in use, accords with the design modulus of elasticity of $4{\cdot}97 \times 10^6$ lb per square inch.

For a bridge built in 1954 at Paguita on the La Guaira-Caracas highway in Venezuela, another long, shallow arch was designed. The actual depth at the crown is 3ft and at the springing 8ft, with a rise of 23ft over a span of 295ft. The site called for minimum horizontal thrust in a markedly skew bridge, since the two abutments rested on soils of completely different physical characteristics. To allow for the difference in rigidity between the crown and the springing, the arch was composed of independent parallel elements tied by transverse members.

Dr. Morandi maintained that an arch was economical to the extent that comparable values of bending obtained throughout its span, and consequently that any great difference in thickness at the crown and at the springing should be avoided. The dimensions of supports should be varied where necessary to bring to bear on the arch the least distortions possible. The logical pursuit of these criteria led to the most satisfying results, both economically and æsthetically.

Turning to details of construction, Dr. Morandi said that he normally chose systems of centering which, upon dismantling, allowed the arch to take its own weight by stages. To save centering when a deep valley had to be crossed, a special technique was used: two half-arches were constructed on the opposing banks and rotated into position. In this way only a central tower of centering was required to support the first half-arch while the equipment was moved to position the second. This technique was used for the Vagli di Sotto footbridge and for the Storms River Bridge, which are both illustrated. The bridge over the Storms River was built across a deep ravine. The arched span of 330ft was built in the following sequence. First, the abutments were constructed and the portions lying between them and two supports built beforehand adjacent to the sides of the ravine. Then the two lateral parts of the roadway, up to the supports on either side of the arch, were built in the normal way. Each of the remaining parts of the arch, between the crown and the portions already built, were built nearly vertically, resting on a hinge. To facilitate the rotation, each part was constructed in two longitudinal halves and the placing of the upper and lower slabs was left. The hinges consisted of two casings of steel plate about 3ft in diameter, one within the other. The construction and the placing of the casings called for the solution of some delicate technical problems.

Rotation into place of the two half-arches was done as follows. The rotating parts were constructed in such a position that their centres of gravity were only 1ft outside the vertical line passing through the hinges of rotation. The rotation was effected first by means of hydraulic jacks placed on the plane of the roadway already built. Then the rotation was continued by the effect of the weight of the rotating bodies themselves, restrained by a braking system comprising a four-geared block and anchorage cables.

As in the case of the Vagli di Sotto footbridge, the bending stresses due to the changing position of the centre of gravity during rotation were corrected by temporary tensioning. A number of steel cables on the top surface were tensioned and relaxed during the course of the operations.

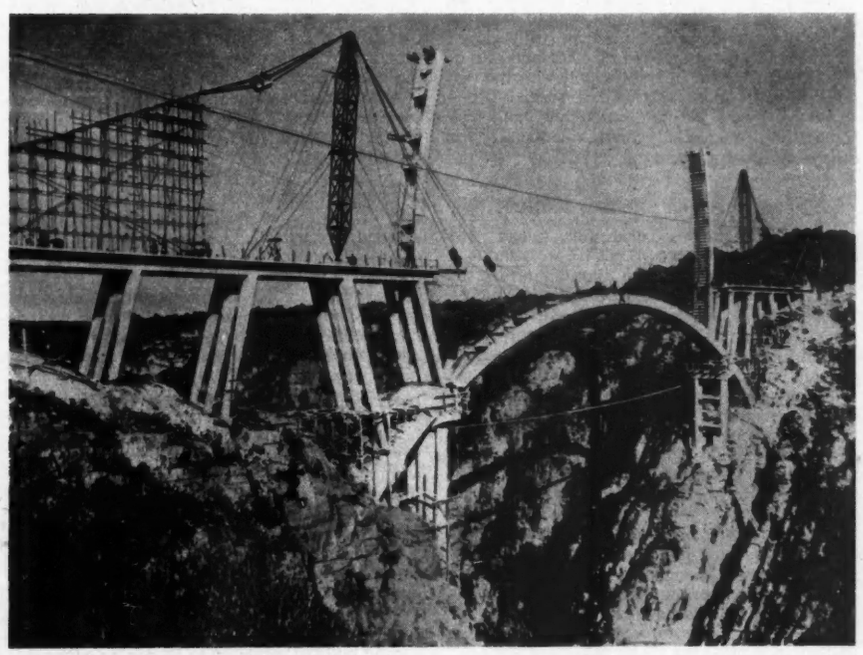
When rotation was finished, the construction of the arch was completed, the hinges were locked and the supports below them removed. After this came the completion of the roadway.

The second part of the lecture was concerned with beam bridges in reinforced concrete and in prestressed concrete. Again, the increase in span, lightness and economy with developments in concrete and steel were shown. A considerably lower relation between dead load and live load per unit of surface was possible with prestressed concrete than with reinforced concrete.

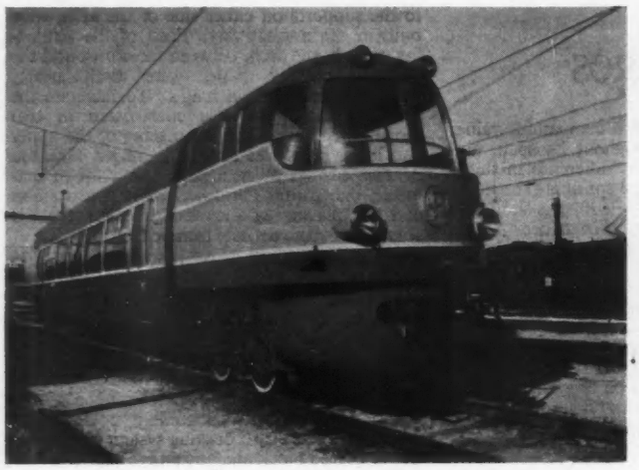
In designing prestressed concrete structures, Dr. Morandi stated that he always took care to see that it should be possible to apply tensioning gradually, in order to correct for any possible deformation; that the steel and concrete should be of such a quality that there should be no danger in approaching the limits of stress; and that, in indeterminate structures, it was helpful to have temporary hinges to accommodate deformations due to prestressing.

Dr. Morandi referred to a series of bridges of 70ft span for which prestressed concrete was used with advantages of lightness and economy, contradicting the normal view that reinforced concrete is more economical for short spans.

He felt that the limit of usefulness of simply



Storms River Bridge, South Africa. Half arches just after positioning. Total arch span 330ft



(Left) "Pendulum" railcar for high-speed tests on standard track. The vehicle will initially be drawn by an electric locomotive, but is to be developed into an electric motor coach. Weight 37 tons, overall length 22·9m (Right) Interior of railcar which is designed to seat thirty-two passengers

supported spans was reached with spans of 125ft. The Carigliano Bridge in the Giunture region, consisting of three parallel frames prestressed throughout, was his first example of an indeterminate structure. For the San Nicola Bridge near Benevento, on State Highway No. 90, a double cantilever frame with articulations at the base was used. The overall length is 390ft, with a clear central span of 260ft.

In recent years, said the speaker, he had studied beams in which tension rods at the ends caused rotations in a sense opposite to that exerted by external loads. This simple arrangement was complicated by the fact the steel for these rods (normally the same as that used for prestressing), being subject to deformation with loading, had very much smaller fatigue strength outside certain limits of stress variation. The selection of these limits was therefore of vital importance. The Amerigo Vespucci Bridge in Florence and the bridge over the Cerami in Sicily, both now under construction, made use of such rods.

For the special case of a bridge over the Oreto at the approaches of the city of Palermo, where a bold and unusual design was called for, it was intended to have a continuous prestressed concrete beam resting on four oblique elastic elements comprising two trestle supports, which were to be hinged upon specially designed foundation structures.

In conclusion, Dr. Morandi discussed his latest project, a bridge 5·6 miles long to cross the Maracaibo Lagoon in Venezuela with eleven central navigable spans, ten of 490ft and one of 1300ft. The central span of 1300ft with the two adjacent 490ft spans, was to have special "X"-shaped supports at the outer ends, and two towers with oblique suspending members at the ends of the central span.

French Experimental Railcar

A "pendulum" experimental railcar was recently completed at the S.N.C.F. workshops at Sotteville, near Rouen, to the design of the French Railways' Bureau of Technical Studies. This prototype, illustrated above, which is now stated to be ready for testing, incorporates several ideas for increasing the stability and improving the comfort of passengers at high speeds.

The main principle of the present design is the suspension of the carriage superstructure between two bogies in such a way that it can swing, pendulum fashion, about a horizontal longitudinal axis. In this way curves can be negotiated without subjecting passengers to centrifugal forces.

One could, of course, theoretically eliminate lateral acceleration by giving the track sufficient superelevation. The extent to which this can be done is, however, limited by the consideration that trains must also be able to travel slowly, or even to stop, on any curve, without throwing an undue strain upon the inner rail.

Superelevation on the fast lines of the French network is therefore limited to a maximum value of 150mm, corresponding to an uncompensated lateral acceleration of $0 \cdot 10g$. As a concrete example, may be quoted the line from Paris to Lyon, where a speed of 140km per hour is permitted in curves of 950m radius with a superelevation of 140mm; this results in an uncompensated acceleration of $0 \cdot 07g$.

Experiments carried out by the S.N.C.F. in 1947–48 showed that accelerations above $0 \cdot 10g$. were very uncomfortable to passengers. If, therefore, the speed of travel is to be raised from 140km per hour to 160km or even 180km per hour in curves of 800m radius and superelevated by 140mm, or if existing maximum speeds are to be raised on branch lines where curves are tighter, then it becomes essential to avoid exposing the passengers to large uncompensated accelerations.

Tests were conducted in February, 1947, on the line Paris–Etampes, with an oscillating compartment set up inside an ordinary carriage. Speeds of 160km per hour in curves of 800m radius were attained. While the resulting lateral acceleration in the carriage was about $0 \cdot 24g.$, a very uncomfortable value, inside the compartment it was only $0 \cdot 06g.$, which is quite admissible. The compartment always adjusted itself so that its inclination was along the resultant of its weight and the centrifugal force.

On the basis of these encouraging results, it was decided to construct a complete full-scale vehicle. It may be mentioned here that similar tests were conducted in America in 1942 with the "Preco-Pendulum" carriage, which, however, made use not of a true pendulum suspension but one employing flexible springs.

A second factor involved in high-speed travel on rails is the need to avoid excessive lateral forces. In order to eliminate dynamic forces due to lateral oscillations, the four wheels of each bogie of the S.N.C.F. vehicle were made independent. It is thought that excessive wear due to the use of independent wheels will be avoided owing to the lightness of the bogies.

Also, in order to minimise oscillations, the trend of thought has been towards a motor coach rather than a locomotive-drawn carriage. In the first instance, however, electric motors have not been fitted, their place being taken by equivalent masses of steel, and the carriage will be drawn by an electric locomotive.

Disc brakes capable of operating at 200km per hour are being used, as they give a better heat dissipation than rim brakes. The low load per wheel, about 4·5 tons, ensures that the amount of energy which must be eliminated is moderate.

As the illustration shows, the S.N.C.F. pendulum car has two bogies. The body is based on a steel girder with swan-necked ends fitted with trunnions which are supported on the columns of the bogies. The axis of rotation is 1·75m above the rails, and the centre of gravity some 0·70m below this height. It is possible for the body to rotate up to 18 deg. to either side of the vertical, without exceeding the loading gauge.

The vehicle has a total weight of 37 tons, which is a low figure in view of the complex mechanical design; the body was constructed from argon-arc welded light alloy. The railcar can seat thirty-two passengers, and has an overall length of 22·9m. The interior is illustrated herewith.

German Oil-Fired Locomotives

With a view to reducing the consumption of coal on the German Federal Railways (DB), it has been decided to convert a number of steam locomotives to oil firing. As a preliminary test a heavy 2–C–1 three-cylinder express engine, series 0110, has been converted to oil. Should expectations be fulfilled, it is intended to convert, by the middle of this year, thirty locomotives of the same class. Maker of the oil-firing equipment is stated to be Henschel and Sohn, Kassel, which carried out the work in co-operation with the DB Central Office at Minden.

It is hoped to realise several advantages besides the savings of coal. For instance, there would not be any difficulties with raising steam due to variations in the quality of coal. Time spent on removing slag and ash is saved, and a range of nearly 1000km can be achieved, compared with 500km to 600km with coal firing. Starting up times are reduced, and maximum output can be reached speedily and without relying upon the physical capacity of the stoker, who is relieved of his very heavy work. Absence of fly ash, smoke and soot will add to the comfort of passengers and will ease the maintenance of the carriages. It is intended to use the converted locomotives on the line Cologne–Hamburg of the Münster Region, and on the line Hanover–Frankfurt/Main–Würzburg, of the Kassel Region.

International Cybernetics Association

At the First International Cybernetics Congress, which was held at Namur in June of last year, the decision was taken to set up an International Cybernetics Association. This was constituted on January 6, 1957, at Namur, and has a present membership of 1000 from twenty-six different countries, of which 300 are industrial firms. It is the object of the Association to form a permanent link between researchers in the different fields of cybernetic study; to further the development of this science, and its technological applications; and to disseminate the results which become known. Full information is obtainable on application to the Permanent Secretariat, 13, rue Basse-Marcelle, Namur (Belgium).

Utilisation of Patents in Germany

A Patent Department for German Research has been formed as a section of the Fraunhofer-Gesellschaft, Munich 19, Romanstrasse 13, which had already been active in this field. The purpose of the new department will be to aid inventors with advice and loans to utilise their patents.

The American Scene

BY OUR AMERICAN EDITOR

Automation in 1957

In recent years, the growing accent on "automation" in the American automobile industry has led to a concentration in the Detroit-Cleveland area of manufacturers of custom-built machine tools. The word "automation" goes far toward explaining the remarkable growth of such firms as the Cross Company of Detroit. Since the end of the last war, this concern has concentrated on the fabrication of "automated" equipment. Once little more than ambitious blueprints, such machines now are hard at work turning out, among other things, intake manifolds, cylinder blocks and parts for jet engines. In time, perhaps, they will lead to the completely automatic factory, in which raw materials flow in at one end, the finished product out the other. These days, to be sure, are prosperous ones for the entire American machine tool industry. Yet the automation part of the industry is growing fastest. According to the American Society of Tool Engineers, approximately 18 per cent of machine tool orders by the metal-working industries called for automation in 1956. By next year, however, the figure is likely to rise to about 25 per cent. Cross, naturally, is not the only concern in the field. Other interesting enterprises include the Snyder Tool and Engineering Company of Detroit, and the Foote-Burt Company of Cleveland. Some of the apparatus produced by these concerns is wondrous to behold. Cross, for example, recently completed a single transfer machine which performs 555 machining operations on V-8 automobile cylinder blocks. In an unbroken sequence, it does 265 drilling operations, 6 milling, 21 boring, 56 reaming, 101 countersinking, and 106 tapping operations, and in the course of all that activity it also performs 133 inspections. The machine, which is 350ft long and has 104 stations, completes 100 blocks an hour. Cross also built and installed the well-known V-8 engine assembly machine at the Detroit engine works of Plymouth. This machine is a quarter of a mile long and performs 280 operations. It takes cylinder blocks in at one end, right cylinder heads at another, and left cylinder heads at a third ; at the end of the line, ready-to-run engines emerge. Similarly, one of Snyder's smaller machines is a twenty-one-station transfer device, which mills, drills, core drills, reams and taps intake manifolds ; tests the manifold for air leakage and air flow ; inspects its own operations progressively ; marks rejects, and, as a final fillip, inserts the heater tubes. It produces 130 pieces an hour. And Foote-Burt now is building three machines, costing more than 1,000,000 dollars each, which have sixty-three stations designed to process motor-car cylinder heads ; this monster can perform 216 operations and turn out 120 pieces an hour. While their products are huge, the automation companies themselves, ironically, are quite small. Many produce only one or two machines a year, and more than half are privately owned. Barely 3 per cent of the firms currently making automation equipment can boast more than 500 employees, 82 per cent have less than fifty. The explanation is not far to seek. The construction of automated machines, to date at least, has been principally a custom engineering affair. In the United States the construction of such single-purpose plant traditionally has been the special province of small machine tool builders. The latter, however, by no means have the field to themselves any more. Several of the larger companies have gone into automation, either by redesigning and adding to their existing lines, or by acquiring firms already in it.

Curiously, despite the ferment it has caused in their industry, the machine tool makers themselves are notably unimpressed by the word "automation." For by now it has become virtually meaningless, to scientists and production engineers alike. Last year, in a report on the subject of "Automation and Technological Change," a Congressional sub-committee noted that "automation" is now applied to such diverse processes as the manufacture of "printed circuitry—etched wiring on a plastic board—and the solution by machine of the most abstruse non-linear partial differential equations." Actually, automation—as well as the technological revolution it has sparked—may be described more precisely. In America, it is to-day considered to fall, roughly speaking, into three main categories. The first, and perhaps the best known, involves the manufacture of computing machines or electronic brains. The second area concerns the fabrication of electronic controls—machines which, endowed with equivalents for human senses, judgment and memory, are used to direct other machines. Some are descendants of a device as simple and familiar as the ordinary thermostat. The third group applies electronic controls to individual machines, thereby making them more automatic, and also assembles heretofore isolated equipment into huge systems. Machines assembled by this latter technique fall into the category known as "transfer equipment," since basically they create linkages between otherwise individual machine tools. More broadly, the same area is often termed "Detroit automation," the major customers for such apparatus, thus far at least, being the makers of cars. The third category is the province of Cross, Foote-Burt, Snyder and the other automated machine tool builders. As they are at pains to point out, transfer machines are no newer than adding machines or thermostats ; machine tool builders for a long time have been linking together individual machining operations by conveyors and other means. However, recent technological advances have made it possible to construct ever larger, more complicated and more automatic units. Equipped with the proper controls, these mechanisms, by meshing and then checking a large group of operations in a manufacturing process, now, in fact, can relegate the worker to the part of the machine's maintenance man. The drive toward the automatic factory has been powered by a single over-riding force—the growing labour shortage. By 1965, according to projections of current trends, the United States will have some 20 per cent more people than at present, but only 14 per cent more workers. In order to keep living standards rising at the current rate, consequently, productivity will have to increase by more than 40 per cent. It has increased only some 34 per cent since World War II. Since machines already perform some 95 per cent of the gainful work done in America, virtually the only way to boost productivity from now on will be to make them more automatic. Hence, the market for its machines, the industry firmly believes, is bound to expand throughout the next decade. In this connection, another favourable economic trend is likely to come into play : the cost of machines, as compared to the cost of labour, has been declining. In fact, according to the Machinery and Allied Products Institute, the price of machinery and equipment, though up some 80 per cent since 1939, has risen only about two-thirds as fast as the cost of labour in the same period.

Despite its impressive achievements the automation industry still has technological difficulties to overcome. One is the problem of building more flexibility into its gigantic tools, so that they do not have to be either scrapped or completely rebuilt by the purchaser with every change in product design. The development of more flexible transfer machines, by allowing buyers more time to amortise their cost, would widen greatly the existing markets for such equipment. There is also the necessity of minimising breakdowns, which, while comparatively minor when a simple device like a lathe is involved, can be catastrophic in a factory-long piece of equipment. Current thinking along these lines calls for "segmenting" transfer machines to make them operate continuously, despite failures in individual components. Snyder, for example, recently developed a system in which individual machines making up a block-long colossus are fitted with separate control panels. When any one unit breaks down, production on the other sections goes on uninterrupted with parts already set aside for that purpose. In one sense this may be a step backward from the concept of a single man pressing a button to activate a quarter of a mile of machinery. However, the customers are demanding such safeguards. In spite of these difficulties there appears to be a promising field ahead for automation equipment. The recent survey of the American Society of Tool Engineers furnishes some indication of just how great that field is. Based on its findings, the A.S.T.E. has concluded that in many industries a substantial percentage of operations can be performed feasibly and economically by automation equipment. Thus, in the automotive industry 20 per cent of all operations could be so performed : 18 per cent in aircraft and engineering, 15 per cent in air conditioning and refrigeration, 16 per cent in electrical engineering, 17 per cent in fabricated metal, 15 per cent in precision equipment, and 7 per cent in machinery. As the A.S.T.E. observes, this adds up to a very substantial market indeed. To "automate" 20 per cent of all automotive operations, for example, would require some 25,000 new machine tools, 10,000 grinders and finishers, and 5000 metal forming machines. Such figures, of course, are approximate. Any errors, however, are apt to be on the conservative side. For all forecasts made to-day are necessarily based on the current state of machine tool technology, rather than its future achievements. If the past be any guide, the industry has by no means reached the end of the line. To cite just one case, "programming" machines by electronic tape control should make rigid systems flexible enough to interest a good many new customers. Automation equipment thus appears to hold high promise, both for those who build it and those who put it to use.

Electrodynamic Calibration of Vibration Pick-ups

The many vibration pick-up instruments which are currently used in the testing of such equipment as guided missiles, aircraft, ships and surface vehicles, demand an extremely accurate means of calibration. To meet this need for accurate vibration measurements the National Bureau of Standards has investigated various methods of calibration and has now standardised an electrodynamic method to be applied to vibration pick-up instruments measuring displacement, velocity or acceleration.

THE National Bureau of Standards, of Washington, D.C., recently developed a method for standardising electrodynamic calibrators which now makes possible a limited N.B.S. calibration service for vibration pick-ups measuring displacement, velocity or acceleration. The method is based on research conducted by S. Levy and R. R. Bouche, of the Bureau's engineering mechanics laboratory with the combined support of the Bureau and the Diamond Ordnance Fuse Laboratories, U.S. Department of the Army. Thousands of vibration pick-ups are now in use by the Government and industry in testing missiles, aircraft, ships, surface vehicles, and other kinds of equipment. The successful

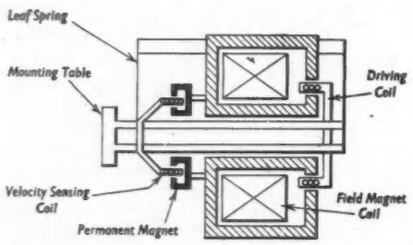


Fig. 1—Diagrammatic cross section of electrodynamic vibration pick-up calibrator developed by the N.B.S.

performance of such machines and the safety of operating personnel depend on the accuracy of observations made with the pick-ups, and therefore on the accuracy of their calibration. To meet this need for an accurate vibration measurement, the Bureau has for some time been investigating various methods for calibrating these pick-ups.

The electrodynamic calibrator for vibration pick-ups consists of a vibration exciter with a built-in vibration measuring device. It produces mechanical vibrations by electrical means and, simultaneously, generates an electrical output that depends on the vibration. The calibrator is standardised by determining the relationship between its electrical output and the vibratory motion. Once an electrodynamic calibrator is standardised, the procedure for calibrating a pick-up is straightforward. The pick-up is attached to the mounting table of the calibrator and is set in vibration at the desired amplitude and frequency. The amplitude can be accurately set as a result of the standardisation procedure and the frequency can be accurately measured. It then remains only to compare the voltage output of the calibrator with that of the pick-up.

The N.B.S. method of standardising the calibrator is based on an improved mathematical analysis of the problem—a more comprehensive reciprocity theory. This method avoids all direct measurement of the vibratory motion itself. It also has the advantage that it can be used above as well as below certain resonances in the calibrator. It is only necessary to measure frequencies, currents and voltages in the calibrator, when (1) several known masses are attached to the mounting table, and (2) when the calibrator is forced to vibrate by an external vibration exciter. The result of the standardising procedure is summed up in two quantities *a* and *b*, which characterise the calibration factor of the calibrator. This factor then expresses the relation between voltage output of the calibrator and the velocity of the mounting table. At higher frequencies, starting at about 900 c/s, it is also necessary to know the mechanical impedance of the pick-up being calibrated. If it is not already known, this impedance can easily be measured with the standardised calibrator.

In calibrating a pick-up, both the magnitude and phase of the pick-up calibration factor can be determined, if desired. Pick-ups calibrated for amplitude only would be suitable for making many vibration measurements in structures. Those calibrated for both amplitude and phase would be suitable as secondary reference standards for governmental and industrial laboratories, or for vibration measurement on structures where phase measurement is desired.

Electrodynamic Calibration

The electrodynamic calibrator for which the present method has been developed has three basic components—a driving coil, a mounting table, and a velocity-sensing coil. These components are the principal moving parts. In the calibrator studied, these parts are joined by a shaft and form a single mechanical unit that is suspended from a frame by leaf springs, as shown in Fig. 1. Also attached to the frame are a field magnet coil near the driving coil and a permanent magnet near the velocity-sensing coil. When alternating current is passed through the driving coil, its magnetic field interacts with that of the field coil, causing the moving parts to vibrate. At the same time, because of the motion relative to the permanent magnet, an alternating voltage is generated in the velocity-sensing coil.

In using the calibrator the pick-up to be calibrated is attached to the mounting table and its electrical output is compared with that of the velocity-sensing coil. If this comparison is to be significant, however, the calibrator must be standardised. Hence, the relation between the electrical output of the velocity-sensing coil and the velocity of the table must be determined. The reciprocity method enables this relation to be calculated without requiring a detailed knowledge of the calibrator structure.

Reciprocity Theorems

Reciprocity theory was first applied to electrical circuits. In the case of a passive linear network, the basic theorem is that if a source of e.m.f. is placed in branch *A* of the network, the current produced in branch *B* is the same as the current that would be produced in branch *A* if the same e.m.f. were inserted in branch *B*. In principle, a corresponding theorem holds for any linear system, including one made up of both electrical and mechanical components. As applied to the electrodynamic calibrator, the reciprocity theorem used states that the ratio of mechanical force at the mounting table to the driving coil current when the velocity of the table is zero (i.e. when it is held fixed) is equal in magnitude and opposite in phase to the ratio of the terminal voltage of the driving coil to the mounting table velocity when the driving coil current is zero (i.e. when its circuit is open).

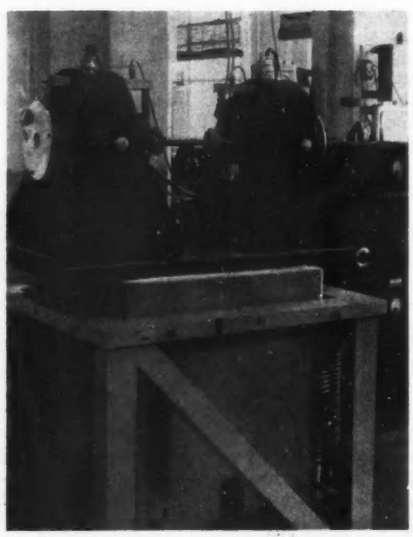


Fig. 2—Apparatus used in voltage ratio measurements for the standardisation of electrodynamic pick-up calibrators by the reciprocity method

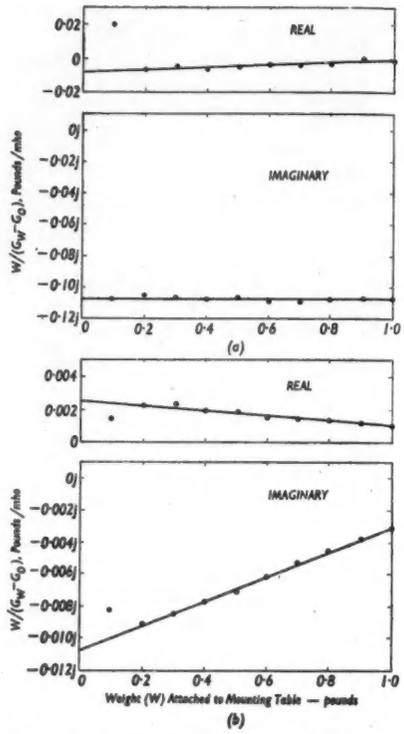


Fig. 3—Results of transfer admittance measurements at frequencies of : (a) 900 c/s, and (b) 5000 c/s, with different weights attached to the mounting table

The reciprocity technique was applied by scientists at the N.B.S. to the calibration of microphones as early as 1940. In 1948, London, Trent, and Thompson showed how the technique could be used to calibrate electromechanical transducers, provided certain conditions were satisfied. One of these conditions is that the connections between the transducers be rigid. This method was applied in 1953 to an electrodynamic calibrator by J. C. Camm, then of the Bureau, in a project supported by the Office of Naval Research. The present work extends the theory by eliminating some of the restrictive assumptions about the structure of the calibrator. In its present form, the theory applies to an electrodynamic calibrator operating in any frequency of amplitude range in which it can be considered linear. Neither the internal structure nor the magnet assembly need be assumed rigid. It applies, for example, not only at low frequencies and at frequencies near certain resonances, but also at frequencies above axial resonance when the driving coil and mounting table move in opposite directions. In addition, the extended theory takes account of electrical coupling between different parts of the same coil and between parts of different coils.

Standardisation Procedure

The standardisation of the calibrator determines the calibration factor *F*, the ratio of induced voltage in the velocity-sensing coil to the mounting table velocity. This factor depends mainly on the characteristics of the calibrator itself, but is also influenced at higher frequencies by the mechanical impedance of the pick-up attached to the table. When a vibration pick-up is attached to the table and the driving coil is

energised with alternating current at any particular frequency the theory shows that

$$F=a+bY_p \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where Y_p is the mechanical impedance of the pick-up and a and b are constants that depend on the construction of the calibrator. All the symbols stand for complex numbers in the manner used in alternating current theory. Thus, Y_p is the complex number that represents in magnitude and phase the ratio of the sinusoidal force applied to the pick-up to the resulting sinusoidal velocity. The aim of the standardisation procedure is to determine the constants a and b. In computing their values transfer admittance and voltage ratio measurements are made.

The transfer admittance G_w, which is the ratio of driving coil current to velocity-sensing coil voltage, is measured with each of several weights W, attached to the mounting table. The transfer admittance G_0, with no weight attached, is also measured. Then for each weight attached to the table the ratio $W/(G_w-G_0)$ is computed. This procedure is repeated at each frequency for which the values of a and b are desired. For each frequency the real and imaginary parts of the computed ratio are plotted against W.

For the voltage ratio measurements the mounting table of the calibrator being standardised is mechanically connected to that of another electrodynamic calibrator or other vibration exciter as shown in Fig. 2. The driving coil in the latter is energised and the ratio R of the open circuit voltage generated in the velocity-sensing coil to the open-circuit voltage generated in the driving coil is measured. This is done for each of the frequencies used in the transfer admittance measurements. The voltage ratio measurements are made, of course, on the calibrator being standardised. Once these measurements have been made the constants a and b are computed from the following equations :—

$$a=0{\cdot}01711\sqrt{j\omega R},\ b=6{\cdot}601\ Q\sqrt{R/j\omega J} \quad . \quad (2)$$

where ω is the frequency in radians per second and j is the unit imaginary vector. The terms J and Q are the ordinate intercept and slope, respectively, of the plot of $W/(G_w-G_0)$ versus W. This completes the standardisation procedure, since the calibration factor can be computed from equation (1) if the mechanical impedance of the pick-up to be attached to the mounting table is known.

The procedure is illustrated in Figs. 3 and 4 by results obtained for a representative electrodynamic calibrator with a nominal 50 lb driving force rating. The calibration factors for this instrument were computed from equation (1) for pick-ups with mechanical impedances corresponding to weights W of 0 lb, 0·5 lb and 1·0 lb. (Y_p is then equal to $j\omega W/g$, where g is 386in per square second.) The magnitude and phase angle of these calibration factors were plotted against frequency in Fig. 4. The graph shows that, for this particular calibrator, the calibration factor is independent of frequency and pick-up weight up to 900 c/s.

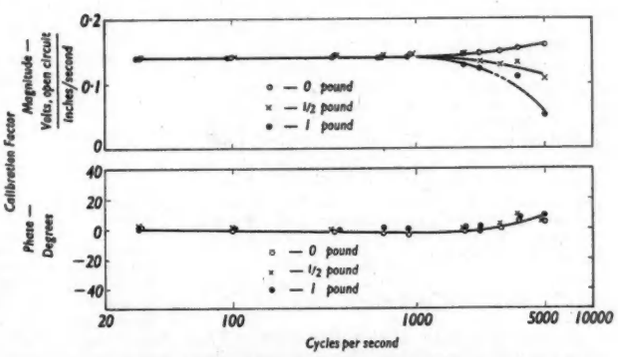


Fig. 4—Variation of pick-up calibration factor with frequency and weight of pick-up, obtained by using the reciprocity method

Calibration of Pick-ups

Ordinarily, before a pick-up can be calibrated, its mechanical impedance Y_p must be known in order to use equation (1) to obtain the calibration factor of the calibrator. If the Y_p of the pick-up is not known it can be measured on an electrodynamic calibrator standardised by the reciprocity method. The theory shows that

$$Y_p=J\left(\frac{\omega}{386}\right)\left(\frac{J(G_p-G_0)}{1-Q(G_p-G_0)}\right) \quad . \quad . \quad . \quad (3)$$

where G_p is the transfer admittance (ratio of driving coil current to velocity-sensing coil voltage) with the pick-up attached to the table. The values of J, Q and G_0 are known from the standardisation of the calibrator. One method of calibrating a pick-up is to energise the driving coil of the calibrator at the desired frequency and drive the calibrator at the desired amplitude as indicated by the voltage in the velocity-sensing coil. From this indicated voltage and the value of F obtained from equation (1) the velocity of the mounting table is found by a simple division, since F is the ratio of velocity-sensing coil voltage to mounting table velocity. The output of the pick-up corresponding to this velocity is

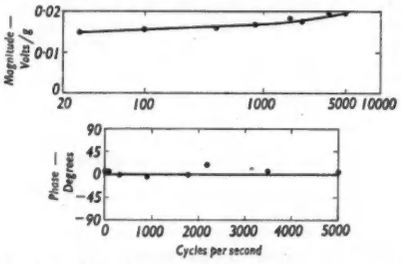


Fig. 5—Calibration of piezo-electric crystal accelerometer showing variation of magnitude and phase of calibration factor with frequency

then measured. The calibration factor of the pick-up is then the ratio of the output of the pick-up to the velocity of the mounting table.

A second method is to measure G_p and the transfer admittance I/E_p, which is the ratio of the current I in the calibrator driving coil to the voltage output E_p of the pick-up. The calibration factor F_p of any accelerometer is then given by

$$F_p=\left(\frac{G_p}{I/E_p}\times\frac{gF}{j\omega}\right) \quad . \quad . \quad . \quad . \quad (4)$$

where $gF/j\omega$ is the acceleration calibration factor of the calibrator. The same method can be used to calibrate velocity and displacement pick-ups, except that equation (4) must be modified by replacing the acceleration calibration factor by the calibration factors for velocity (F) or displacement ($j\omega F$), respectively. For example, in the case of a piezo-electric accelerometer the transfer admittance G_p was measured with the device attached to the mounting table and its mechanical impedance Y_p was found from equation (3). The results of this calibration are shown in Fig. 5. The other quantities in equation (3) were known from the calibrator standardisation data. The calibration factor F could then be obtained from equation (1). After measuring the transfer admittance I/E_p, the calibration factor of the pick-up F_p was computed from equation (4).

The calibration of a variable resistance accelerometer, illustrated in Fig. 6, was done in a similar manner. In determining the calibration factor for such a pick-up at frequencies other than those at which the calibrator was standardised it was necessary to interpolate for a, b, R and Q and to compute J from equation (2). This interpolation was used only at frequencies below 900 c/s, in which range the interpolation leads to no appreciable error, for the calibrator used. It was found in the calibration of these pick-ups that the term bY_p in equation (1) was negligibly small compared to the term a at frequencies up to 900 c/s. In such cases the procedure in both of the above methods is considerably simplified. Once the calibrator has been standardised it is easy to predict the frequency range in which the term bY_p can be neglected.

Among the resonant conditions of the calibrator studied are the following, in their usual order of appearance with increasing frequency : resonance of mounting table and coils as a rigid body on the guiding leaf springs ; local resonance in the leaf springs ; transverse resonance of the shaft connecting the mounting table and driving coil ; longitudinal resonance of the same shaft, and local resonance in the mounting table or coils. The longitudinal resonance of the driving coil relative to the velocity-sensing coil reduces the accuracy of the reciprocity calibration over a small frequency range. This is because R at resonance is very small and therefore difficult to measure and because at resonance the large amplitude of the driving coil may exceed its linear range.

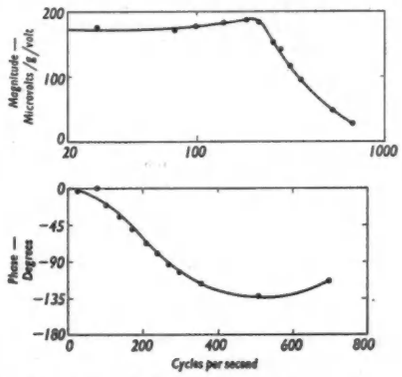


Fig. 6—Calibration of variable resistance accelerometer showing variation of magnitude and phase of calibration factor with frequency

Transverse motion from any source invalidates the reciprocity method, since the latter requires the mounting table to have uni-axial motion. Usually, transverse motion occurs at frequencies for which the leaf springs or shaft are in transverse resonance. The leaf springs of some calibrators can be de-tuned, thus changing the frequency at which resonance occurs, by repositioning small weights attached to them.

Several electrodynamic calibrators standardised by the reciprocity method are now in service at the Bureau for the calibration of vibration pick-ups. A redetermination of the constants a and b for one of the N.B.S. calibrators showed no significant change after the lapse of a year. With respect to frequency, the calibration factors of the standards have been found to be constant within 1 per cent up to 900 c/s. At higher frequencies the calibration factor is known with somewhat less accuracy because of flexibility in the standard as a result of longitudinal resonances. This flexibility changes the electromechanical characteristics of the standards and results in less stability at the higher frequencies. Plans are now being considered to modify the standards to achieve an accuracy of 1 per cent at higher frequencies.

Gold-Coated Molybdenum for Turbine Blades.—To improve the resistance to high-temperature corrosion of molybdenum for turbine blades, the metal can be coated by electroplating with metals such as nickel and chromium. Despite such plating, however, it has been found that the microscopic boundaries between the grains of nickel or chromium allow air to come in contact with the molybdenum, causing rapid oxidation with the formation of molydenum trioxide at temperatures up to 1800 deg. Fah. It has been discovered at the Battelle Institute that a thin gold film offers additional protection. The procedure is to plate the molybdenum with a layer of chromium, followed by a thin layer of gold, and then by additional layers of nickel and chromium. The work upon which this process is based was described in a paper " Properties of Electrodeposits at Elevated Temperatures," by W. H. Safranek and G. R. Schaer at the forty-third annual convention of the American Electroplaters' Society, Washington, D.C.

Personal and Business

Appointments

MR. R. E. HARRIS, sales manager of Expandite (South Africa) (Pty.), Ltd., has been appointed a director.

MR. STANLEY N. LOOSEN has been appointed sales director of the Anti-Attrition Metal Company, Ltd., Maidenhead.

BIRFIELD INDUSTRIES, Ltd., has announced the appointment of Mr. E. J. Power as executive director of the automotive division.

MR. STANLEY S. DAWES, M.I.Mech.E., has been elected president of the Institute of the Motor Industry for the year 1957/58.

MR. J. W. BOLT has been appointed chief engineer of Henry Robb, Ltd., Leith, in succession to Mr. W. Y. Craig, who has retired.

MR. J. O. HITCHCOCK, a director of the Mond Nickel Company, Ltd., has been appointed a director of Henry Wiggin and Co., Ltd.

THE BRITISH REFRIGERATION ASSOCIATION states that Mr. D. S. Carruthers has been elected chairman and Mr. E. G. Rowledge vice-chairman.

BLACK AND DECKER, Ltd., states that Mr. J. P. Jamieson has been appointed sales manager of its industrial and automotive range of portable electric tools.

MR. D. MARTIN has been appointed chief engineer of Alan Muntz and Co., Ltd., and will be in charge of free-piston engine design and test development at Feltham.

ALLDAYS AND ONIONS, Ltd., has announced that Mr. Leonard Lee, M.I.Mech.E., has been appointed managing director in succession to Mr. J. Erskine, who has retired.

DR. PAUL EISLER has been made an officer of the French "Order of Merit for Research and Invention," for his invention and pioneering work of printed circuits.

THE ELECTRICAL ASSOCIATION FOR WOMEN states that the Dowager Lady Swaythling has relinquished the office of president and has been succeeded by the Viscountess Kilmuir.

VICKERS, LTD., announces that Mr. C. L. Old, M.I.C.E., M.I.Mech.E., principal of the College of Technology, Wolverhampton, has been appointed group education officer.

THE BRITISH TRANSPORT COMMISSION has announced the appointment of Mr. R. G. Sell as assistant (fixed equipment), electrical engineering department, 14, Melbury Terrace, London, N.W.1.

BRAYSHAW FURNACES AND TOOLS, Ltd., has announced that Councillor W. G. Pallett has been appointed managing director. Mr. W. T. C. Roden has been appointed technical general manager.

ALFRED HOLT AND CO. announces the retirement of Mr. A. G. Arnold from the post of chief superintendent engineer, after forty-three years' service with the company, and the appointment of Mr. J. B. Peacock as his successor.

W. C. HOLMES AND CO., Ltd., has announced the appointment of Mr. A. J. M. Henshaw as general sales manager. Mr. W. Sykes has taken over responsibility for the contracts, erection and buying departments in addition to his present duties.

AIR MARSHAL SIR CHARLES GUEST has been appointed aeronautical adviser to the Minister of Transport and Civil Aviation, and chairman of the Air Safety Board in succession to Air Chief Marshal Sir Frederick Bowhill, who is retiring from his post.

THE BRITISH ROPEWAY ENGINEERING COMPANY, Ltd., states that Mr. H. F. Shields has been appointed chairman and consultant director. Mr. G. F. B. Harvey has been appointed deputy chairman and joint managing director in conjunction with Mr. M. Clayton as joint managing and technical director.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., states that Dr. W. H. Darlington, chief engineer, gas turbine engineering and gear engineering departments, has been awarded the 1956 Silver Medal of the Institute of Marine Engineers for his paper "Some Considerations of Wear in Marine Gearing."

THE FAIREY AVIATION COMPANY, Ltd., announces the following appointments :—Dr. G. S. Hislop has been appointed deputy chief engineer and retains his position as chief designer (rotating wing) ; Mr. D. Wakeford has been appointed chief designer (fixed wing) ; Mr. C. W. Cowle, deputy chief designer ; and Mr. G. M. Spinks and Mr. W. C. Scott, assistant chief designers.

VICKERS, LTD., states that the board of Vickers-Armstrongs (Tractors), Ltd., is now constituted as follows :—Major-General C. A. L. Dunphie, chairman ; Mr. A. P. Wickens, managing director ; Mr. W. J. R. Cupples, commercial director ; Mr. G. F. Onions, director in charge of Onions Works, Bilston ; Mr. J. R. Hendin, general manager, Scotswood ; Mr. L. F. Little, chief engineer, Scotswood ; Mr. A. H. Hird, Mr. P. H. Muirhead and Mr. E. J. Waddington, directors. The following executive appointments have also been made :—Mr. R. L. Lawson, general manager, Onions Works, Bilston; Mr. G. Moray Stephenson, sales manager ; Mr. G. A. Barrett, works manager, Scotswood ; Mr. J. G. Castle, commercial manager, Scotswood ; Mr. N. de Lacey, field service manager ; Mr. J. A. Fiddian, commercial manager, Onions Works, Bilston ; and Mr. W. H. James, dealer service manager. Mr. Lawson and Mr. Moray Stephenson have also been appointed special directors.

Business Announcements

MR. ERIC TOWN, director and general manager of Fredk. Town and Sons, Ltd., has left this country to visit South Africa.

REED BROTHERS (ENGINEERING), Ltd., states that it has moved from Millwall to a site on the new Woolwich industrial estate.

MR. F. SHAKESHAFT, A.M.I.E.E., mechanical engineering consultant, of the Central Electricity Authority, has relinquished his appointment.

AUTO DIESELS, Ltd., Uxbridge, announces that its industrial engine division, operating under the trade name "Stad," will market the Standard IS/250 gas turbine.

MR. D. W. MANSELL, executive director of the National Gas and Oil Engine (Export) Company, Ltd., has left London by air for a round-the-world sales tour.

DALLOW, LAMBERT AND CO., Ltd., Leicester, states that, with effect from June 20, its London address will be 6, Stratton Street, W.1 (telephone, Grosvenor 4766).

MR. ALAN KIERNAN, M.I.Mech.E., has relinquished his appointment as assistant managing director of Edward G. Herbert, Ltd., owing to ill health. He retains his seat on the board.

MR. JAMES HENDRY, M.I.Mech.E., sales director of the pump and compressor division of Hamworthy Engineering, Ltd., has retired. His services have been retained in a consultative capacity.

JOHNSON AND PHILLIPS, Ltd., states that Mr. Charles J. H. Stevens, F.R.S.A., manager of the cable accessories department, has retired after forty-four years' service with the company.

CHAMBERLAIN INDUSTRIES, Ltd., has announced that it has appointed W. and J. R. Watson, Ltd., 81, Great King Street, Edinburgh, 3, as official agent in Scotland for the "Staffa 3" mobile crane.

THE DUNLOP RUBBER COMPANY, Ltd., states that the Semtex office has been moved from 123, Pall Mall to care of Alfred Goslett and Co., Ltd., 127, Charing Cross Road, London, W.C.1 (telephone, Gerrard 7890).

MARCONI'S WIRELESS TELEGRAPH COMPANY, Ltd., states that Mr. J. A. Smale, M.I.E.E., has retired from the post of engineer-in-chief of Cable and Wireless, Ltd., and has been appointed technical consultant in telecommunications engineering to Marconi's.

THE MARCONI MARINE COMMUNICATION COMPANY, Ltd., states that its offices at Marconi House, Chelmsford, Essex, have been connected to the G.P.O. Telex system. The Telex number is 20-3771, and telegrams should be addressed "Thulium Chelmsford-Telex."

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., has announced that General Sir William D. Morgan has resigned from the boards of Associated Electrical Industries, Ltd., Siemens-Ediswan Ltd., Siemens Brothers and Co., Ltd., and the Edison Swan Electric Company, Ltd.

Contracts

TAYLOR WOODROW CONSTRUCTION, Ltd., has been awarded by the Central Electricity Authority a contract for the construction of the second stage of the foundations for the High Marnham power station in Nottinghamshire. The firm's contract there now comprises the whole of the main foundations and circulating water works for the station's five 200MW turbo-alternator sets. This work is valued in all at £4,250,000 and is expected to be completed in the summer of 1961. Messrs. Freeman, Fox and Partners are the consulting engineers for the civil engineering and building works.

Miscellanea

RESEARCH AIRCRAFT.—The Short S.C.1. vertical take-off and landing research aircraft made its first flight last week from Boscombe Down. The flight was entirely in the normal low-incidence regime. The machine was illustrated on December 21, 1956, page 895.

TEXTILE PROCESSING TECHNIQUE.—Under this heading in our issue of March 22 we described a new textile processing technique which incorporates a fluid bed. Our attention has been drawn by the English Glass Company, Ltd., of Empire Road, Leicester, to the fact that that company supplied the ballotini used on the fluid bed research which we referred to.

STRUCTURAL ENGINEERING CONFERENCE.—The Institution of Structural Engineers is holding a conference in 1958 to celebrate its fiftieth anniversary. The conference will be held from October 7 to 10, 1958, at the headquarters of the Institution, and its theme will be "The Future of Structural Engineering." Sessions will be arranged to cover the whole field of structural engineering.

NEW GOODS DEPOT FOR BARKING AREA.—A new goods depot is being built at Ripple Lane, near Barking, to replace an existing depot near Barking station, the site of which is required in connection with the rearrangement of running lines and flyover scheme at Barking, on which work is now in progress. Initially, the new depot will deal with sundries, full load, coal and storage traffic, at present dealt with at the existing yard, but the land in the immediate vicinity will later be available for redevelopment and the goods depot will then be extended. Ultimately, the new depot will be concerned with the collection and delivery of goods by road over a wide area.

UGANDA ELECTRICITY BOARD.—An extensive programme of the Uganda Electricity Board for the years 1956–1960 was passed by the Legislative Council of Uganda on March 14 ; the borrowing powers of the Board were raised from £27,000,000 to £33,000,000. This programme forms part of Uganda's capital development plan up to the year 1960. Excluding any expenditure on a second dam which the Board is now considering, the Board expects to spend about £6,000,000 on main transmission, distribution fed by hydro-electric power from the Owen Falls scheme, and on self-contained schemes for up-country stations, which are too remote to be supplied from Owen Falls.

RAILWAY CIVIL ENGINEER'S TRAINING CENTRE.—A training centre has been set up by the chief civil engineer of the Eastern Region of British Railways at King's Cross, to give initial instruction in the basic principles of drawing-office and fieldwork to suitable young men. The normal training syllabus will be of six months' duration and, apart from railway civil engineering, will embody suitable tuition in the general conduct of the railways as a business and the functions of the various departments. At the completion of the training course the students are to be drafted to positions within the department or transferred to the student civil engineers' scheme.

BUILDING PLANT EXHIBITION.—We are informed that the Minister of Works, the Rt. Hon. Hugh Molson, M.P., will open this year's Building Plant Exhibition at Heaton Park, Manchester, on Monday, July 15. The exhibition, which will be open from July 15 to 20 inclusive, is the eleventh in the series organised by the Ministry of Works since 1950 for the purpose of showing the modern machines, equipment and tools which are available to the building and civil engineering industries and which can help increase efficiency and reduce costs. Some forty manufacturers and distributors have already booked space and their exhibits will be representative of the whole range of equipment available to the industry.

USES OF TIMBER.—Arrangements have been made to hold a symposium on the uses of timber at Lodge Hill Residential College, Pulborough, Sussex, from October 11 to 15, 1957. The symposium has been designed to provide practical information to practising architects, engineers and surveyors on the structural use of timber and plywood. Papers will be given on such subjects as qualities and grading, specification, moisture in wood, durability and preservation. It is also intended to include talks and discussions on the physical and mechanical properties of timber, the properties of adhesives, the application of timber and plywood to structures, and developments in timber engineering. Details of the symposium can be obtained from the Regional Officer, Timber Development Association, Ltd., 8, St. George's Place Brighton, 1, Sussex.

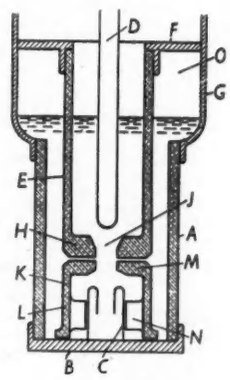
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

ELECTRICAL ENGINEERING

769,781. June 3, 1955.—EXTINGUISHING CHAMBER FOR OIL BLAST ELECTRIC CIRCUIT BREAKERS, Allmanna Svenska Elektriska Aktiebolaget, Vasteras, Sweden.

The invention relates to an extinguishing chamber for an oil blast electric circuit breaker, especially for small breaking capacities. The object is to provide an extinguishing chamber having small dimensions, a considerable breaking capacity and a simple design. In the drawing, *A* is an insulating cylinder closed at the bottom by a metal cover *B*, to which the stationary contact *C* of the circuit breaker is attached. The movable contact is a pin contact *D*. In the cylinder *A* there is arranged a further insulating cylinder *E*, which at the upper end is attached by an annular cover *F* to a metal cylinder *G* fastened to the upper end of the cylinder *A*. The cylinder *E* has a bottom *H* with an opening *J* for the passage of the movable contact. Below the bottom *J* there is a dome *K* which consists of an insulating cylinder *L* with a cover *M*, with an opening for the passage of the movable contact. The dome *K* is provided with



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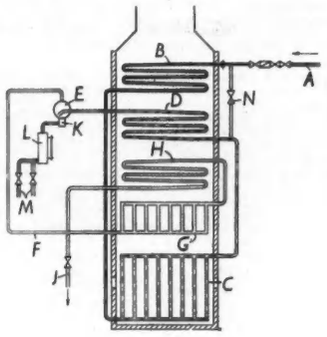
fins or other inwardly extending members *N* which slide against the stationary contact *C* or against a sleeve surrounding this contact, whereby the motion of the dome *K* is guided axially. The extinguishing chamber is filled with oil to a certain height, but above the oil level, between the cylinders *E* and *F*, there is a space *O* which is filled with air or some other gas. The arrangement acts in the following way. When the contacts *C* and *D* separate, an arc is formed in the space bounded by the dome *K*. The pressure generated by the arc lifts the dome so that the cover *M* is forced against the bottom *H*, thus closing the slot between these parts. Simultaneously at the lower edge of the dome *K* an opening is formed for the passage of the oil into the space between the cylinders *A* and *E*, so that the oil level in this space will be raised and the gas in the space *O* compressed. When, later, upon continued motion of the contact *D* upwards, the current through the arc decreases towards zero, the pressure inside the dome *K* falls, so that the pressure outside may move it downwards, so that the bottom *H* and the cover *M* separate. The pressure in the space *O* will then force the oil through the slot between these parts towards the arc.—*March* 13, 1957.

STEAM GENERATORS

770,091. May 2, 1955.—METHODS OF REMOVING SALT FROM FORCED-FLOW ONCE-THROUGH STEAM BOILERS, Siemens-Schuckertwerke Aktiengesellschaft, Berlin and Erlangen, Germany.

Referring to the drawing, feed water enters through a pipe *A* into a forced-flow tube system and passes through an economiser *B*, a radiation evaporator *C*, and a final evaporator *D*, thence passing in the form of dry saturated steam, usually slightly super-heated, to a separator *E*. The separator is connected by pipes *F* to a superheater *G* which in turn is followed by a convection superheater *H* and the steam outlet pipe *J*. The purpose of the separator *E*, which during normal operation is traversed by dry steam, is to remove water from the steam when flushing the boiler. The lower part of the separator is provided with a number of cyclones *K*, of known construction. A collecting tank *L* is provided for precipitated liquor, and drain pipes *M* are fitted to the tank. When it is desired to flush the tubing an appropriately increased amount of water is supplied to some of the parallel tubes of the evaporator *D*, for instance, to two of them, through valves *N*, so that the evaporation does not proceed to the production of dry steam. Wet steam then leaves the tubes and passes from the tubing to the separator *E*, where the unevaporated



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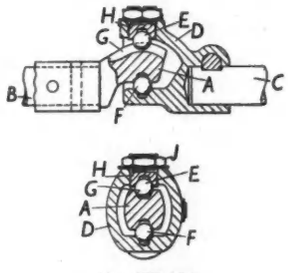
water is removed, together with the salt, while the steam flows on through the pipe *F* to the superheater *G*. The invention is concerned with the problem of salt removal in the case of large forced-flow once-through boilers wherein the boiler tubes are subdivided into two parts which operate in parallel and which can be regulated separately, and an example of its application to such a boiler is also given in the specification.—*March* 13, 1957.

POWER TRANSMISSION

770,186. April 1, 1954.—UNIVERSAL JOINTS, Burman and Sons, Ltd., Wychall Lane, King's Norton, Birmingham, 30, and Walter Henry Briggs, of the company's address.

The invention relates to universal joints for interconnecting and transmitting motion between two rotary shafts. Referring to the drawing, a member *A* is formed on or secured to one end of a shaft *B* to be connected to a shaft *C*, and on the adjacent end of the shaft *C* is secured a complementary socket *D* in which the member *A* is contained. The member *A* is off-set from the axis of the shaft *B* and at one side is formed with an outwardly curved peripheral surface of segmental form having a longitudinal groove *G*. Also the complementary socket *D* is likewise off-set from the axis of the shaft *C*. The



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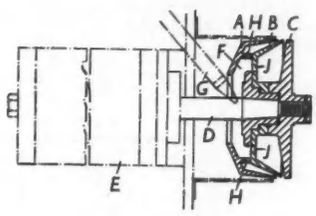
member *A* is held in position by a pair of coaxial pivot pieces *E* and *F*, each of which is a ball. The ball *F* is arranged with its centre on the longitudinal axes of the two shafts, and at the centre of curvature of the grooved surface of the member *A*. This ball engages recesses formed in the adjacent parts of the socket and member *A*. The other ball *E* engages the groove *G* in the member *A* and a recess in the adjacent end of an adjusting screw *H*.—*March* 20, 1957.

BURNERS AND SPRAYERS

770,530. February 24, 1954.—LIQUID FUEL ATOMISERS, Joseph Lucas (Industries), Ltd., Great King Street, Birmingham, 19. (*Inventors: Owen Napier Lawrence and Leslie Augustus Walker.*)

The invention relates to fuel atomisers for use as liquid fuel burners, comprising a rotary bowl, such that fuel supplied to the interior of the bowl is caused by centrifugal force to be discharged over the lip of the bowl in the form of a film which is disintegrated by surface tension to provide the required spray. The object is to provide an atomiser in a form which can deal effectively with fuel supplied at a rate which may vary over a wide range. As shown in the drawing, two separate coaxial bowls, *A* and *B*, are nested one within the other. The annular discharge orifice from the first bowl *A* is formed by its lip and the adjacent outer surface of the second bowl *B*. The annular discharge orifice of the second bowl *B* is formed by its lip and a circular plate *C* secured to the second bowl adjacent to its open end. The two bowls are carried by a common spindle *D* driven by a motor *E*. In the base of the first bowl *A* is formed an annular fuel reception chamber *F* to which fuel can be supplied by a feed pipe *G*. In the periphery of this chamber is a ring of ports *H* leading to the first discharge orifice, and in the base of the second bowl there is a ring of ports *J* through which fuel can pass from the reception chamber to the second discharge orifice. The arrangement is such that so long as the rate of supply



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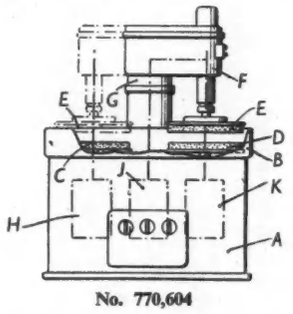
of fuel does not exceed a predetermined limit, the fuel occupies, under centrifugal force, only that portion of the periphery of the reception chamber which is immediately adjacent to the ports *H*, and fuel is then supplied only to the first discharge orifice. But when this rate of supply is exceeded the quantity of fuel in the reception chamber is such that it can also pass through the ports *J* to the second discharge orifice. By arranging for the bowls to become operative successively, atomisation of the fuel can be effected satisfactorily over a wide range of rate of supply of the fuel. Any desired number of coaxial bowls may be employed, each additional bowl having ports in its base through which fuel can pass from the preceding bowl.—*March* 20, 1957.

MACHINE TOOLS

770,604. June 13, 1955.—LAPPING MACHINES, Frank Christopher Potts, 12, Church Street, Liverpool, 1. Communicated by the firm Hahn and Kolb, Stuttgart, Germany.

The invention relates to an improved lapping machine in which the workpieces held in supports are treated between two discs arranged vertically one above the other. The upper lapping disc is mounted on a pivoted arm by which it can be moved out of the region above the lower lapping disc to interchange the workpieces. According to the invention, two lower lapping discs are provided side by side, and the upper lapping disc may be selectively swung on its pivoted arm over either of the lower lapping discs. As will be seen in the drawing, the machine base *A*, which is rectangular and is enclosed on all sides, has an open trough *B* in which two lower lapping discs *C* and *D* are arranged side by side



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on vertical shafts in the machine base. An upper lapping disc *E* may be raised and lowered in a pivoted arm *F*. The pillar *G*, about which the arm pivots is disposed centrally between the two lower lapping discs. The pivoting movement of the arm is limited between the two positions in which the upper disc *E* is coaxially located above each of one of the two lower discs. Each of the three lapping discs is driven through a transmission mechanism by an electric motor. The electric motors, *H*, *J* and *K*, are shown in chain-dotted lines. The drive to the upper lapping disc *E* is taken from the motor *J* through the pillar *G* and the pivoted arm *F*. In order that various working speeds may be obtained, motors are constructed as pole-changing three-phase motors. Each motor has a pole-change switch located on the front of the machine, by which the direction of rotation and the three-speed stages of the motors may be selected.—*March* 20, 1957.

Launches and Trial Trips

BRITISH VALOUR, oil tanker ; built at the Wallsend yard of Swan, Hunter and Wigham Richardson, Ltd., for B.P. Tanker Company, Ltd. ; length between perpendiculars 640ft, breadth moulded 86ft, depth moulded 48ft, deadweight 32,000 tons on 35ft draught, service speed 15½ knots ; thirty cargo oil tanks, one main cargo pump room, three 850 tons per hour turbine-driven centrifugal cargo pumps, three vertical stripping pumps ; two 600kW geared turbine-driven alternators, one 150kW diesel-driven alternator, one 75kW steam-driven alternator ; one set of Wallsend Slipway double reduction geared turbines, 15,500 maximum s.h.p. at 112 propeller r.p.m., taking steam at 600 lb per square inch and 850 deg. Fah. from two Babcock and Wilcox selectable superheat water-tube boilers.—Launch, December 19.

CITY OF AUCKLAND, cargo liner; built at the Walker Yard of Vickers-Armstrongs, Ltd., for Ellerman Lines, Ltd.; length between perpendiculars 470ft, breadth moulded 66ft 6in, depth moulded 42ft, summer draught 28ft, deadweight 10,200 tons ; service speed 15¼ knots ; five main holds ; Vickers-Doxford six-cylinder oil engine, 8000/8800 b.h.p. Launch, December 28.

ROZENNO, trawler ; built by the Chantiers Augustin-Normand for Robert Engelhart, Lorient ; length overall 122ft 9in, length between perpendiculars 111ft 7in, breadth moulded 23ft 8in, depth 13ft 6in, mean draught 11ft 1in, speed 12 knots ; fish hold capacity 5300 cubic feet, one supercharged Duvant diesel engine with reverse reduction gear, 750 h.p. Trial, December.

ICE PRINCESS, coaster ; built by the Chantiers et Ateliers du Rhin for John Kyvik, of Haugesund, Norway ; length overall 243ft 5½in, breadth moulded 33ft 6in, depth to shelter deck 20ft 8in, deadweight 1700 tons, draught 12ft 8in (open shelter), 15ft (closed shelter), speed 12 knots ; one L.A.K. mark M.AU. 581.A. diesel engine, 1450 h.p. at 300 r.p.m. Trial, December.

CANIGOU, cargo ship ; built by the Forges et Chantiers de la Mediterranée for the Cie. de Navigation Mixte ; length overall 293ft 8in, breadth moulded 44ft, depth to shelter deck 25ft 7in, draught 16ft 9in, deadweight 1600 tons, trial speed 15 knots ; three holds, two 5-ton and four 10-ton derricks, one Sulzer mark 6.S.D.60 diesel engine, 3000 h.p. at 150 r.p.m. Trial, December.

LONDON VALOUR, oil tanker ; built by Furness Shipbuilding Company, Ltd., for London and Overseas Freighters, Ltd. ; length overall 593ft, length between perpendiculars 560ft, breadth moulded 80ft, depth moulded 42ft 3in, deadweight 24,900 tons on 32ft 4½in summer draught ; twenty-seven cargo oil compartments, one main cargo pump room, three 1000 tons per hour turbine-driven centrifugal pumps, three 150 tons per hour vertical stripping pumps ; two 325kW turbine-driven generators, one 75kW diesel-driven generator ; one set of Richardsons Westgarths double reduction geared turbines developing 7300 s.h.p. at 100 propeller r.p.m. and a maximum of 8200 s.h.p. at 104 r.p.m. Steam supplied at 450 lb per square inch and 750 deg. Fah. by two Foster Wheeler " D " pattern water-tube boilers. —Trial, December.

ABERDEEN CITY, trawler ; built by Alexander Hall and Co., Ltd., for Aberdeen Motor Trawlers, Ltd.; length between perpendiculars 113ft, breadth 25ft, depth 12ft 6in ; fish room 6700 cubic feet, 115 h.p. electric trawl winch, barrel capacity 650 fathoms, 2¾in warp, 95kW diesel-driven winch generator ; Mirrlees mark KSDM-6 diesel engine ; 760 b.h.p. at 250 r.p.m. Launch, January 14.

MERCHANT ROYAL, cargo ship ; built by the Blythswood Shipbuilding Company, Ltd., for the Drake Shipping Company, Ltd.; length 470ft, breadth 63ft 2in, depth to upper deck 41ft 6in, deadweight 12,600 tons on closed shelter deck draught of 28ft 10¾in ; five cargo holds, one 30-ton and ten 10-ton derricks, electric winches ; two 160kW diesel-driven and two 80kW steam-driven generators ; Rowan-Doxford opposed-piston, two-cycle diaphragm oil engine, five cylinders, 700mm diameter by 2320mm combined stroke, 6200 b.h.p., trial speed 16½ knots. Trial, January 22.

BEN SCREEL, trawler ; built by John Lewis and Sons, Ltd., for R. Irvin and Sons, Ltd.; length between perpendiculars 120ft, breadth 25ft, depth 12ft 6in, fish room 7000 cubic feet, electric trawl winch barrel capacity 1000 fathoms of 2¾in warp ; Mirrlees " K.S.S.6 " diesel engine, 712 b.h.p. at 220 r.p.m. Trial, January 24.

CORSEA, collier ; built by Hall Russell and Co., Ltd., for William Cory and Son, Ltd.; length between perpendiculars 320ft, breadth moulded 46ft, depth moulded 22ft 4in, deadweight 4600 tons ; five self-trimming holds, electric deck machinery, three 75kW diesel-driven generating sets ; Clark-Sulzer single-acting, two-stroke, diesel engine, 1300 b.h.p. at 162 r.p.m. in service. Trial, January.

Catalogues and Brochures

AUSTINLITE, Ltd., Crawley, Sussex.—Publication dealing with automatic power plant and control switchgear. Examples are given illustrating different combinations of plant engineered as typical installations for specific purposes, together with some of the problems in the manufacture of automatic power plant which have been encountered.

TRINIDAD AND TOBAGO ELECTRICITY COMMISSION, 63, Frederick Street, Port-of-Spain, Trinidad.—Illustrated souvenir brochure commemorating the official commissioning of the Metropolitan-Vickers 10MW steam turbine generating unit by His Excellency Sir Edward Betham Beetham, Governor of Trinidad and Tobago.

GRUNDIG ELECTRONIC G.M.B.H., Fürth, Bavaria, German Federal Republic.—The present state of the Grundig programme of precision measuring equipment is shown on twenty-eight illustrated pages which list the main technical data and descriptions of over twenty electronic and other instruments. The brochure contains details of instruments still under development, and a price list is added.

STURTEVANT ENGINEERING COMPANY, Ltd., Southern House, Cannon Street, London, E.C.4.—Illustrated publication entitled " The ' Precipitron ' Air Filter," (third edition), describing the application of air filtration equipment. The booklet aims to encourage discrimination in the choice of air filtration equipment and the " Precipitron " electrostatic filter is described in great detail. Publication No. 3502, describing some of the fans for mechanical draught manufactured.

MIDLAND SILICONES, Ltd., 19, Upper Brook Street, London, W.1.—A new technical data sheet, reference No. C25–1, describing the properties of " Megasil 1400 " varnish, this is a modified silicone dipping and impregnating varnish, formerly available for limited evaluation as MS1400. Typical curing schedules are listed and tables are given indicating the measure of the new product's moisture repellency, bond strength and solvent resistance in relation to organic varnishes.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, April 12.—BRISTOL AND W. OF ENGLAND BRANCH : Royal York House Hotel, Bath, " The Calder Hall Film," 8 p.m. ★ STOKE AND CREWE BRANCH : Royal Hotel, Crewe, " Electrical Fire Alarms," R. B. Whitehouse, 7.30 p.m.

CHEMICAL SOCIETY

To-day, April 12.—Anniversary Meetings, 1957, at Cambridge.

ILLUMINATING ENGINEERING SOCIETY

Mon., April 15.—LEICESTER CENTRE : Royal Hotel, Leicester, Annual General Meeting, 6 p.m.
Tues., April 16.—GLOUCESTER AND CHELTENHAM CENTRE : Belle Vue Hotel, Cheltenham, Annual General Meeting, 6.30 p.m.
Fri., April 19.—LIVERPOOL CENTRE : Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, " Modelling with Light and Colour," A. Wilcock, 6 p.m.

INCORPORATED PLANT ENGINEERS

Tues., April 16.—S. WALES BRANCH : S. Wales Engineers' Institute, Park Place, Cardiff, " Gas in Industry," 7.15 p.m.
Wed., April 17.—KENT BRANCH : Kings Head Hotel, High Street, Rochester, " The Plant Engineer and Work Study," H. A. Gomm, 7 p.m.
Thurs., April 18.—BLACKBURN BRANCH : Golden Lion Hotel, Blackburn, Brains Trust, Sir Oliver Lyle and Dr. Oliver, 7.30 p.m. ★ MERSEYSIDE AND N. WALES BRANCH : Stafford Hotel, City Road, Chester, " Industrial Hydraulics," D. V. Rowles, 7.15 p.m.

INSTITUTE OF PHYSICS

To-day, April 12.—LIVERPOOL AND N. WALES BRANCH : Denbighshire New Technical College, Wrexham, " The Industrial Utilisation of Radiation," R. Roberts, 7 p.m. ★ NON-DESTRUCTIVE TESTING GROUP : 47, Belgrave Square, London, S.W.1, " Damping Capacity and Fatigue," K. M. Entwhistle, 6.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., April 15.—SCOTTISH CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Annual General Meeting, 7.30 p.m.
Tues., April 16.—N.E. CENTRE : Three Tuns Hotel, Durham City, Annual General Meeting, 7 p.m.
Wed., April 17.—N. REGIONAL CENTRE : Victoria and Station Hotel, Preston, Annual General Meeting, 7.30 p.m.
Thurs., April 18.—YORKSHIRE CENTRE : Great Northern Hotel, Wellington Street, Leeds, Annual General Meeting, 7.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., April 16.—N.W. BRANCH : Engineers' Club, Albert Square, Manchester, Joint Meeting with the Institute of Petroleum, " Forty Years On—If the Oil Wells Run Dry," E. S. Sellers, 6.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., April 16.—ORDINARY MEETING : Great George Street, Westminster, London, S.W.1, " Railway Diesel Traction and Associated Problems," A. B. Henderson, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., April 15.—INFORMAL MEETING : Savoy Place, London, W.C.2, Discussion on " The Future of Plastics in Power Cables," opened by C. C. Barnes, 5.30 p.m. ★ N. STAFFORDSHIRE SUB-CENTRE : Duncan Hall, Stone, Informal Evening on " Electronics and Automation," talk on " Some Industrial Applications," H. A. Thomas, 7 p.m.
Tues., April 16.—MEASUREMENT AND CONTROL SECTION : Savoy Place, London, W.C.2, Discussion on " The Measurement of Currents in High-Voltage Circuits without Orthodox Current Transformers," opened by M. Kaufmann and A. J. King, 5.30 p.m. ★ S.E. SCOTLAND SUB-CENTRE : Carlton Hotel, North Bridge, Edinburgh, " An Introduction to Some Technical Factors Affecting Point-to-Point Radio Communication Systems," F. J. M. Laver, 7 p.m. ★ N. MIDLAND CENTRE UTILIZATION GROUP : Central Electricity Authority, 1, Whitehall Road, Leeds, " Electrical Floor Warming," J. W. Moule and W. M. Stevenson, 6.30 p.m.
Wed., April 17.—SHEFFIELD SUB-CENTRE : Grand Hotel, Sheffield, " The B.B.C. Sound Broadcasting Service on Very-High Frequencies," E. W. Hayes and H. Page, 6.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Mon., April 15.—E. OF SCOTLAND BRANCH : Royal British Hotel, Dundee, Annual General Meeting, 7.30 p.m.
Wed., April 17.—BIRMINGHAM BRANCH : Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, " Cost Aspects of Quality Control," C. J. Anson, 7.30 p.m.
Thurs., April 25.—N.W. BRANCH : Engineers' Club, Albert Square, Manchester, " Recent Developments in Workshop Metrology," John R. Adams, 7.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Tues., April 16.—39, Elmbank Crescent, Glasgow, " The Analysis of Plain Bearing Failures," P. P. Love, 6.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

To-day, April 12.—MANCHESTER AND DISTRICT BRANCH : County Offices, Preston, " Modern Methods of Oil Firing," 6.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., April 24.—GENERAL MEETING : Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, " Painting and Cleaning of Rolling Stock," F. Fancutt, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Tues., April 16.—LONDON GRADUATES' SECTION : 1, Birdcage Walk, Westminster, London, S.W.1, " Pneumatic Controllers for Process Control," K. S. Jones, 6.30 p.m.
Wed., April 17.—INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on " The Importance of Internal Communications in an Engineering Works," 6.45 p.m.
Thurs., April 18.—YORKSHIRE GRADUATES' SECTION : Chemistry Lecture Theatre, University, Leeds, Annual General Meeting, 6.30 p.m.
Thurs., April 25.—STEAM GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on " Removal of External Deposits on Boilers," 6.45 p.m. ★ N.W. GRADUATES' SECTION : Engineers' Club, Albert Square, Manchester, Annual General Meeting, 6.45 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., April 25.—GENERAL MEETING : Geological Society of London, Burlington House, Piccadilly, London, W.1, " Trace Elements in Sphalerite, Galena and Associated Minerals from the British Isles," E. M. El Shazly, J. S. Webb and D. Williams and " Stratigraphical and Structural Ore Controls on the Slitt Vein at Heights Mine, Weardale, Co. Durham," R. J. P. Lyon and B. Scott, 5 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Wed., April 17.—INFORMAL MEETING : Waterloo Bridge House, London, S.E.1, " D.C. Signalling : Are its Days Numbered," R. F. Howard, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Wed., April 17.—WOLVERHAMPTON AND WOLVERHAMPTON GRADUATE SECTION : Wolverhampton and Staffordshire Technical College, Wolverhampton, " Modern Trends in the Application of Pneumatics," R. Cooper, 7.15 p.m. ★ PETERBOROUGH SECTION : White Lion Hotel, Church Street, Peterborough, " Production of Raw Materials from Rolling Mills," J. McLauchlan, 7.30 p.m.
Thurs., April 18.—S.E. REGION : Royal Empire Society (Craven Street Entrance), Northumberland Avenue, Strand, London, W.C.2, " The Corporate Responsibilities of Production Engineers," Austen Albu, 7 p.m.

INSTITUTION OF PUBLIC HEALTH ENGINEERS

Tues., April 16.—Caxton Hall, Caxton Street, Westminster, London, S.W.1, " The Effect of Mining Subsidence on Public Health Engineering," R. J. Orchard, 6 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., April 15.—MANCHESTER SECTION : Engineers' Club, Albert Square, Manchester, Annual General Meeting, 6.45 p.m.
Thurs., April 25.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, Annual General Meeting, 6.45 p.m.
Fri., April 26.—MERSEYSIDE SECTION : Stork Hotel, Liverpool, Annual General Meeting, 6.15 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, April 12.—MIDLAND COUNTIES GRADUATES' AND STUDENTS' SECTION : Birmingham Exchange and Engineering Centre, Birmingham, Chairman's Address, F. J. Pardoe, 6.30 p.m.
Wed., April 17.—YORKSHIRE BRANCH : Central Electricity Authority, Leeds, Annual General Meeting, followed by " Civil Engineering Construction Under Water," J. R. Malcolm, 6.30 p.m.
Tues., April 30.—WALES AND MONMOUTHSHIRE BRANCH : S. Wales Institute of Engineers, Cardiff, " Wind Stresses on Buildings," H. Ferrington, 6.30 p.m.

INSTITUTION OF WATER ENGINEERS

Mon., April 15.—S.E. SECTION : Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, " River Board Functions," C. H. H. Mercer, 2.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, April 12.—ORDINARY MEETING : Pepys House, 14, Rochester Row, Westminster, London, S.W.1, " Electric Locomotive Design," F. J. G. Haut, 7 p.m.

LIVERPOOL ENGINEERING SOCIETY

Wed., April 17.—24, Dale Street, Liverpool, Annual General Meeting, 6 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, April 12.—Lecture Theatre, Mining Institute, Newcastle upon Tyne, " Marine Machinery Breakdowns," J. H. Milton, 6.15 p.m.
Mon., April 15.—TEES-SIDE BRANCH : Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, " Failure of Welded Steel Structures," T. W. Bushell, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., April 16.—SECTION LECTURE : 4, Hamilton Place, London W.1, " Simulation Techniques in Aeronautics," J. J. Foody and R. A. Paul, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Wed., April 17.—QUANTITY SURVEYORS' GENERAL MEETING : Hoare Memorial Hall, Church House, Great Smith Street, London, S.W.1, Discussion on " Elemental Bills," opened by E. R. Parrinder, 6 p.m.

ROYAL METEOROLOGICAL SOCIETY

Wed., April 17.—49, Cromwell Road, London, S.W.7, Annual General Meeting, 5 p.m.

ROYAL SOCIETY OF HEALTH

To-day, April 12, *to Fri., May* 31.—90, Buckingham Palace Road, London, S.W.1, Exhibition on " Atoms and Health," Mondays to Fridays, 10 a.m. to 5 p.m.

ROYAL STATISTICAL SOCIETY

Wed., April 17.—London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1, Discussion on " The Use of Electronic Data Processing Equipment," opened by J. H. H. Merriman, D. T. Caminer, H. L. Barman and H. Durant, 5.15 p.m.

SOUTH WALES INSTITUTE OF ENGINEERS

Thurs., April 18.—Park Place, Cardiff, " Underground Filling of Hydrox and Cardox," Stanley Atherton, 6 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

To-day, April 12.—39, Elmbank Crescent, Glasgow, Annual General Meeting, followed by " Continuous Casting," J. R. Rippon, 6.45 p.m.